



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

Stanford University Libraries

3 6105 000 865 894







[REDACTED] [REDACTED]



PUBLICATIONS
OF THE
ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI.
NUMBER 61.
1904.

SAN FRANCISCO,
PRINTED FOR THE SOCIETY
1904.

[Entered at Post Office at San Francisco, Cal., as Second-Class Matter, 1904.]



PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI.

NUMBER 94.

1904.

SAN FRANCISCO.

PRINTED FOR THE SOCIETY.

1904.

[Entered at Post Office at San Francisco, Cal., as Second-Class Matter, May 1, 1903.]





NEBULA N. G. C. 6992 IN *CYGNUS*.

By G. W. RITCHIEY.

(By courtesy of the Editors of the *Astrophysical Journal*.)

PUBLICATIONS
OF THE
ASTRONOMICAL SOCIETY
OF THE PACIFIC.

VOLUME XVI

1904.

1904

SAN FRANCISCO:
PRINTED FOR THE SOCIETY.

1904.

120207

YHAFUJ
ROHUL OROBAT OHA BU
YT293VINU

MICROFILM AVAILABLE
MICROFILM AVAILABLE

PUBLICATIONS

OF THE

Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, FEBRUARY 10, 1904. No. 94

LIST OF MEMBERS

OF THE

ASTRONOMICAL SOCIETY OF THE PACIFIC.

JANUARY 1, 1904.

OFFICERS OF THE SOCIETY.

Mr. OTTO VON GELDERN	President
Mr. S. D. TOWNLEY	First Vice-President
Mr. W. W. CAMPBELL	Second Vice-President
Mr. CHAS. S. CUSHING	Third Vice-President
Mr. R. G. AITKEN	Secretaries
Mr. F. R. ZIRL	
Mr. F. R. ZIEL	Treasurer

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, LEUSCHNER, MOLERA, VON GELDERN, PIERSON, TOWNLEY, ZIRL.

Finance Committee—Messrs. PIERSON CUSHING, LEUSCHNER.

Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.

Library Committee—Messrs. TOWNLEY (Librarian), RICHARDSON, MISS O'HALLORAN.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

LIST OF MEMBERS.*

Prof. R. G. AITKEN	{ Lick Observatory, Mt. Hamilton, Cal.
Mr. SEBASTIAN ALBRECHT	{ Lick Observatory, Mt. Hamilton, Cal.
Prof. W. STEADMAN ALDIS,* F.R.A.S.	{ Kidlington, near Oxford, England.
Prof. W. D. ALEXANDER*	{ Box 732, Honolulu, Hawaiian Islands.
Mr. RICHARD H. ALLEN*	Chatham, Morris Co., N. J.
Miss EDITH W. ALLYNE	2609 Gough St., S. F., Cal.

*A star signifies Life Membership. Total membership, 255 (67 life members).

Mr. CHARLES ALTSCHUL.....	{ Lazard Frères & Co., 10 Wall St., New York, N. Y.
Hon. WILLIAM ALVORD*.....	2548 Jackson St., S. F., Cal.
Dr. G. DEL AMO.....	{ Plaza de Santa Barbara No. 2, Madrid, Spain.
ASTRONOMICAL AND PHYSICAL OBSERVATORY	{ Taschkent, Turkestan, Russia.
Dr. A. J. ATKINS.....	{ 494 and 496 Parrott Building. S. F., Cal.
Mr. J. J. AUBERTIN,* F.R.A.S.....	{ 33 Duke St., St. James, S. W., London, England.
Mr. ALLEN H. BABCOCK.....	1216 Webster St., Oakland, Cal.
Mr. B. A. BAIRD.....	{ U. S. Coast and Geodetic Survey, P.O.Box 2512, S. F. Cal.
Mrs. ADDIE L. BALLOU.....	{ Room 62, 1170 Market St., S. F., Cal.
Mr. GEO. A. BATCHELDER.....	Menlo Park, Cal.
Mrs. A. N. BELCHER.....	1298 Van Ness Ave., S. F., Cal.
Mr. PAUL M. BENEDICT.....	Box 637, New Haven, Conn.
Mr. JOHN BERMINGHAM*.....	330 Market St., S. F. Cal.
Mrs. BEVAN.....	{ 46 Queen's Gate Terrace, S. W., London, England.
Prof. ALBERT S. BICKMORE.....	{ American Museum of Natural History, Central Park, New York, N. Y.
Mr. R. L. BISCHOFFSHEIM,* F.R.A.S.....	3 Rue Taitbout, Paris, France.
Mr. CHARLES R. BISHOP.....	Occidental Hotel, S. F., Cal.
Mr. THOMAS B. BISHOP*.....	532 Market St., S. F., Cal.
Mr. ANSON STILES BLAKE.....	Berkeley, Cal.
Mr. J. W. BLESSING.....	Risingsun, Ohio.
Mr. HENRY LORD BOULTON, JR.,* F.R.A.S.....	{ Carácas, Venezuela, or Box 2015, New York, N. Y.
Prof. F. P. BRACKETT.....	{ Pomona College, Claremont, Cal.
Mr. FREDERICK E. BRASCH.....	{ Harvard College Observatory, Cambridge, Mass.
Mr. J. A. BRASHEAR, F.R.A.S.....	Allegheny City, Pa.
Rev. M. S. BRENNAN.....	{ St. Lawrence's Church, St. Louis, Mo.
Mr. EDWARD M. BREWER.....	27 Kilby St., Boston, Mass.
Mr. CHARLES BURCKHALTER, F.R.A.S.....	{ Chabot Observatory, Oakland, Cal.
Miss MARY E. BYRD.....	{ The Observatory, Smith College, Northampton, Mass.
Dr. J. CALLANDEAC*.....	{ Oradour sur Vayres, Haute Vienne, France.
Prof. W. W. CAMPBELL.....	{ Director Lick Observatory, Mount Hamilton, Cal.
Mr. ANDREW CARNEGIE*.....	{ 5 West 51st St., New York, N. Y.

Mr. J. C. CEBRIAN*	{ Pine and Octavia Sts., S. F., Cal.
Mr. RAY E. CHASE.....	Chico, Cal.
Mr. H. C. CHESBROUGH	300 California St., S. F., Cal.
Mr. MATEO CLARK*.....	{ 9 New Broad St., E. C., London, England.
Mr. A. L. COLTON*.....	Box 1148, Madison, Wisconsin.
Major S. COMFORT.....	{ Standard Oil Co. of New York, Bombay, India.
Mr. J. COSTA.....	114 Montgomery St., S. F., Cal.
Dr. RUSSEL TRACY CRAWFORD.....	{ Students' Observatory, Berkeley, Cal.
Mr. GEORGE CROCKER*.....	Mills Bldg., New York, N. Y.
Mr. HENRY J. CROCKER.....	185 Crocker Bldg., S. F., Cal.
Mr. WILLIAM H. CROCKER*.....	{ Crocker-Woolworth National Bank, S. F., Cal.
Hon. EDWARD CROSSLEY,* F.R.A.S.....	{ Bermerside Observatory, Halifax, England.
Miss S. J. CUNNINGHAM.....	{ Swarthmore College, Delaware Co., Pa.
Mr. RALPH CURTISS.....	{ Lick Observatory, Mt. Hamilton, Cal.
Mr. CHAS. S. CUSHING.....	104 Sutter St., S. F., Cal.
Mr. PAUL DANA.....	<i>The Sun</i> , New York, N. Y.
Mr. J. EWEN DAVIDSON*.....	{ 98 Banbury Road, Oxford, England.
Mr. E. A. DENICKE.....	1000 Mason St., S. F., Cal.
Mrs. JOHN H. DEVEREUX.....	{ 882 Euclid Ave., Cleveland, Ohio.
Mr. GEO. L. DILLMAN, C.E.....	917 Grand St., Alameda, Cal.
Mr. CECIL GOODRICH DOLMAGE.....	{ 243 Cromwell Road, S. W. London, England.
LL.D., D.C.L., F.R.A.S.	
Mr. J. A. DONOHUE.....	{ Vice-Prest. Donohoe - Kelly Banking Co., S. F., Cal.
Mrs. ANNA PALMER DRAPER*.....	{ 271 Madison Ave., New York, N. Y.
Rev. W. ARTHUR DUCKWORTH, J.P.....	{ Orchardleigh, Frome, Somerset, England.
Mr. FRANCIS G. DU PONT.....	Montchanin, Del.
Mr. ERNEST I. DYER.....	1383 Alice St., Oakland, Cal.
Miss S. J. EASTMAN.....	Ogontz School, Pa.
Prof. GEORGE C. EDWARDS.....	2546 Dana St., Berkeley, Cal.
Mr. R. H. E. ESPEY.....	{ Room 4, 4th floor Mills Building, S. F., Cal.
FIELD MEMORIAL OBSERVATORY.....	{ Williams College, Williamstown, Mass.
Hon. ROBERT ISAAC FINNEMORE,*F.R.A.S.....	{ Puisne Judge, Supreme Court, Pietermaritzburg, Natal, South Africa.
Mr. J. H. FIREHAMMER.....	615 Larkin St., S. F., Cal.
Mr. S. WILSON FISHER.....	1502 Pine St., Philadelphia, Pa.
Mr. ANDREW B. FORBES*.....	401 California St., S. F., Cal.

Mr. GEORGE STUART FORBES.....	{ Care King, King & Co., East India Agts., Bombay, India.
Mr. ARTHUR W. FOSTER*.....	322 Pine St., S. F., Cal.
Mr. FRED R. FRENCH.....	{ Room 3, City Hall, Brockton, Mass.
Mr. H. C. FRICK*.....	42 5th Ave., Pittsburgh, Pa.
Mr. ROBERT D. FRY*.....	1812 Jackson St., S. F., Cal.
Mr. WALTER F. GALE, F.R.A.S.....	Paddington, Sydney, N. S. W.
Mr. J. D. GALLOWAY.....	1426 Myrtle St., Oakland, Cal.
Mr. OTTO VON GELDERN.....	{ Room 89, Flood Building, S. F., Cal.
Sir DAVID GILL, C.B., F.R.A.S.....	{ Royal Astronomer, Cape of Good Hope, Africa.
Dr. A. F. GILLIHAN.....	{ Students' Observatory, Ber- keley, Cal.
Mr. ELWYN B. GOULD.....	{ 808 Juniper St., San Diego, Cal.
Mr. ADAM GRANT*.....	{ N. E. cor. Bush and Sansome Sts., S. F., Cal.
Mr. JOSEPH D. GRANT*.....	{ N. E. cor. Bush and Sansome Sts., S. F., Cal.
Mr. WM. GRANT.....	104 Sutter Street, S. F. Cal.
Mr. H. T. S. GREEN.....	{ London, Paris & American Bank, S. F., Cal.
Mr. ANDREW GREIG*.....	{ 3 Duntrunc Terrace, Broughty Ferry, Dundee, Scotland.
Mr. J. O'B. GUNN.....	222 Market St., S. F., Cal.
Mr. C. F. HARMS.....	{ 140 Broad St., New York, N. Y.
Mr. R. WALDO HARRISON.....	{ 165 Clinton Ave., Jersey City, N. J.
Mr. JACKSON HATCH.....	Porter Building, San José, Cal.
Mrs. PHEBE A. HEARST.....	{ Room 33, 9th floor, Mills Building, S. F., Cal.
Mr. ANDREW P. HENKEL.....	{ 2706 Kleine St., Cincinnati, Ohio.
Mr. CHAS. B. HILL.....	212 Pine St., S. F., Cal.
Mr. HORACE L. HILL*.....	124 Sansome St., S. F., Cal.
Miss ADELAIDE M. HOBE.....	604 Capp St., S. F., Cal.
Mr. SAMUEL V. HOFFMAN,* F.R.A.S.....	{ 91 Madison Ave., Morristown, N. J.
Dr. EDWARD S. HOLDEN*.....	{ U. S. Military Academy, West Foreign Assoc. R.A.S. { Point, N. Y.
Mr. JOHN D. HOOKER.....	{ 325 West Adams St., Los Angeles, Cal.
Hon. C. WEBB HOWARD*.....	Pacific-Union Club, S. F., Cal.
Mr. WM. HOWAT*.....	{ 458 William St., Melbourne, Victoria.
Prof. CHAS. S. HOWE.....	{ Case Observatory, Cleveland, Ohio.
Prof. W. J. HUSSEY.....	{ Lick Observatory, Mt. Ham- ilton, Cal.

Mrs. M. H. HUTTON.....	{ 26 Union St., New Brunswick, New Jersey.
IMPERIAL OBSERVATORY.....	{ University of St. Petersburg, Russia.
Mr. EDWARD IRVING.....	{ 1530 Shattuck Ave., Berkeley, Cal.
Mr. FRANK JAYNES.....	{ W. U. Telegraph Co.,* S. F., Cal.
Mr. CHARLES C. KEENEY*.....	{ 2220 Clay St., S. F., Cal.
Mr. JAMES R. KELLY.....	{ 309 Leavenworth St., S.F., Cal.
Prof. A. E. KENNELLY,* F.R.A.S.....	{ Division of Engineering, Harvard University, Cambridge, Mass.
Mr. DONALD KING.....	{ 8 Church Lane, Hornsey, London, England.
Mr. WM. H. KNIGHT.....	{ 1012 West Eighth St., Los Angeles, Cal.
Mr. TORVALD KÖHL*.....	{ Odder, Denmark.
Mr. FR. KOEPPEN.....	{ Schöne Aussicht 20, Wiesbaden, Germany.
Prof. H. KREUTZ.....	{ Kiel, Germany.
Mr. C. F. DE LANDERO*.....	{ P. O. Box 1, Pachuca, State Hidalgo, Mexico.
Prof. EDGAR L. LARKIN.....	{ Director Mount Lowe Observatory, Echo Mountain, Cal.
Hon. MANUEL FERNANDEZ LEAL.....	{ Casa de Moneda, City of Mexico, Mexico.
Rev. Prof. E. LEDGER, M.A., F.R.A.S.....	{ Protea, Reigate, Surrey, England.
Prof. A. O. LEUSCHNER.....	{ Students' Observatory, Berkeley, Cal.
Mr. CLARENCE MACKENZIE LEWIS*.....	{ Care Wm. Salomon & Co., 25 Broad St., New York, N. Y.
CALIFORNIA STATE LIBRARY.....	{ Sacramento, Cal.
LIBRARY OF THE CHABOT OBSERVATORY..	{ Oakland, Cal.
THE CITY LIBRARY.....	{ Lowell, Mass.
FREE PUBLIC LIBRARY.....	{ Worcester, Mass.
THE JOHN CRERAR LIBRARY.....	{ Chicago, Ill.
LIBRARY OF THE LELAND STANFORD JR. UNIVERSITY	{ Stanford University, Cal.
LIBRARY OF THE LICK OBSERVATORY....	{ Mount Hamilton, Cal.
LIBRARY OF THE MECHANICS' INSTITUTE.	{ 31 Post St., S. F., Cal.
LIBRARY OF THE MINNEAPOLIS ATHE- NÆUM	{ Minneapolis, Minn.
NEW YORK PUBLIC LIBRARY.....	{ 40 Lafayette Place, New York, N. Y.
LIBRARY OF PRINCETON UNIVERSITY....	{ Princeton, New Jersey.
THE PUBLIC LIBRARY.....	{ Boston, Mass.
LIBRARY OF ST. IGNATIUS COLLEGE.....	{ 214 Hayes St., S. F. Cal.
LIBRARY OF THE U. S. MILITARY ACADEMY	{ West Point, N. Y.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA	{ Berkeley, Cal.
LIBRARY OF THE UNIVERSITY OF ILLINOIS	{ University Station. Urbana, Illinois.
LIBRARY OF THE UNIVERSITY OF INDIANA	{ Bloomington, Indiana.
LIBRARY OF THE UNIVERSITY OF PENNSYLVANIA	{ Philadelphia, Pa.
LIBRARY OF THE UNIVERSITY OF SOFIA..	Sofia, Bulgaria, Europe.
LIBRARY OF YALE UNIVERSITY.....	New Haven, Conn.
Mr. ADOLPH LIETZ.....	422 Sacramento St., S. F., Cal.
Mr. JOHN D. LOCKE.....	Haverhill, New Hampshire.
Mr. HENRY B. LOOMIS*.....	Seattle, Washington.
Mr. W. H. LOWDEN.....	314 California St., S. F., Cal.
LOWELL OBSERVATORY.....	Flagstaff, Arizona.
Mr. EDWARD G. LUKENS.....	200 Market St., S. F., Cal.
Hon. GEO. RUSSELL LUKENS.....	1350 Madison St., Oakland, Cal.
Mr. FRANK E. LUNT.....	{ Care R. G. Lunt, Los Angeles, Cal.
Mr. JAMES D. MADDRILL.....	{ Lick Observatory, Mt. Hamilton, Cal.
Mr. MARSDEN MANSON, C.E., PH.D.....	530 California St., S. F., Cal.
Mr. F. MARTENS.....	{ Collegepoint, Queens Co., New York.
Hon. E. S. MARTIN.....	P. O. Box 75, Wilmington, N. C.
Mr. JOHN MARTIN.....	{ Puruatanga, Martinborough, Wairarapa, Wellington, New Zealand.
Prof. A. M. MATTOON.....	{ Scott Observatory, Parkville, Missouri.
Mr. W. H. MAW,* F.R.A.S.....	{ 18 Addison Road, Kensington, London, England.
Mr. FRANK McCLEAN,* M.A., F.R.A.S....	{ Rusthall House, Tunbridge Wells, England.
Mr. F. H. McCONNELL.....	14 Post St., S. F., Cal.
GARRETT W. McENERNEY.....	Nevada Block, S. F., Cal.
Prof. T. E. McKINNEY.....	Marietta College, Marietta, Ohio.
Mr. JOHN L. McNAB.....	Ukiah, Cal.
Prof. MALCOLM McNEILL.....	Lake Forest, Ill.
Prof. E. MILLER.....	{ University of Kansas, Lawrence, Kansas.
Dr. HARRY EAST MILLER.....	331 Pine St., S. F., Cal.
Hon. D. O. MILLS*.....	15 Broad St., New York, N. Y.
Mr. JAMES K. MOFFITT.....	First National Bank, S. F., Cal.
Mr. E. J. MOLERA,* C.E.....	606 Clay St., S. F., Cal.
Mr. W. H. S. MONCK, F.R.A.S.....	{ 16 Earlsfort Terrace, Dublin, Ireland.
Mr. FREMONT MORSE, U.S.C. & G.SURVEY..	P. O. Box 2512, S. F., Cal.
Mr. WILLIAM S. MOSES.....	{ Turk St., bet. Masonic and Parker Aves., S. F., Cal.
Mr. C. A. MURDOCK.....	2710 Scott St., S. F., Cal.

Hon. B. D. MURPHY*	530 California St., S. F., Cal.
Mr. CHARLES NELSON	6 California St., S. F., Cal.
Mr. H. F. NEWALL,* F.R.A.S.	{ Observatory of the University, Cambridge, England.
Dr. B. L. NEWKIRK	2218 Union St., Berkeley, Cal.
Mr. P. NOORDHOFF	Groeningen, Holland.
Miss ROSE O'HALLORAN	1718 Baker St., S. F., Cal.
Miss M. A. ORR	{ Holly Cottage, Milford, Surrey, England.
Governor GEORGE C. PARDEE	Sacramento, Cal.
Mr. JOHN PATTEN*	{ 325 E. 97th St., New York, N. Y.
Hon. GEO. C. PERKINS*	Oakland, Cal.
Prof. C. D. PERRINE	{ Ass't Astronomer, Lick Observatory, Mt. Hamilton, Cal.
HON. JAMES D. PHELAN	301 Phelan Building, S. F., Cal.
Mr. HENRY PHIPPS, JR.*	{ Carnegie, Phipps & Co., Pittsburgh, Pa.
Mr. JOHN JAY PIERREPONT	{ 1 Pierrepont Place, Brooklyn, Kings Co., N. Y.
Mr. LAWRENCE H. PIERSON	Pacific Pine Co., S. F., Cal.
Hon. WM. M. PIERSON,* F.R.A.S.	{ 230 Montgomery St., S. F., Cal.
Mr. RUTHVEN W. PIKE*	{ 1945 Orrington Ave., Evanston, Illinois.
Miss JULIET PORTER*	37 Deane St., Worcester, Mass.
Mr. CHARLES A. POST, F.R.A.S.	Bayport, Long Island, N. Y.
Mr. WALTER A. POST	Newport News, Virginia.
Mr. ENOS PUTMAN*	Grand Rapids, Michigan.
Mr. J. C. RABE	{ P. O. Box 301, Mare Island, Vallejo, Cal.
Mr. CARL RAMUS	{ Ass't Surgeon U. S. Marine Hospital, S. F., Cal.
Rev. J. L. RICARD, S.J.	Santa Clara, Cal.
Mr. DANIEL S. RICHARDSON	{ Cor. Lincoln and Summit Sts., East Oakland, Cal.
Mrs. ISAAC ROBERTS	{ Starfield, Crowborough, Sussex, England.
Mrs. ARTHUR RODGERS*	{ Leavenworth and Vallejo Sts., S. F., Cal.
Dr. W. H. ROLLINS	250 Marlboro St., Boston, Mass.
The EARL OF ROSSE, F.R.A.S.	{ Birr Castle, Parsonstown, Ireland.
Baron ALBERT VON ROTHSCHILD*	Vienna, Austria.
Mr. ALEXANDER RYDZEWSKI	{ Officer St., House 13, Lodging 26, St. Petersburg, Russia.
Mr. JOHN W. SALSBUURY	Port Tampa City, Florida.
Prof. J. M. SCHAEBERLE*	{ 502 Second St., Ann Arbor, Mich.
Mr. JACOB H. SCHIFF*	932 Fifth Ave., New York, N. Y.
Mrs. E. T. SCHILD	1908 Broadway, S. F., Cal.

Dr. M. SCHIRMAN.....	6 Eddy St., S. F., Cal.
Dr. FRANK SCHLESINGER.....	{ Yerkes Observatory, Williams Bay, Wisconsin.
Mr. HERMAN SCHUSSLER.....	Pacific-Union Club, S. F., Cal.
Mr. JAMES L. SCOTT, F.R.A.S.....	{ Care Scott, Harding & Co., Shanghai, China.
Prof. FREDERICK H. SEARES.....	Columbia, Mo.
Dr. J. M. SELFIDGE.....	Box 37, Oakland, Cal.
Mr. S. E. SLADE.....	6 California St., S. F., Cal.
Mr. CHARLES S. SMITH*.....	25 W. 47th St., New York, N. Y.
Mr. SOMMERS N. SMITH.....	{ The Neafie & Levy Ship and Engine Building Co., Phila- delphia, Pa.
Mr. WM. H. SMYTH.....	101 Sansome St., S. F., Cal.
Prof. M. B. SNYDER.....	{ Director of the Philadelphia Observatory, Philadelphia, Pa.
Mr. A. B. SPRECKELS*.....	327 Market St., S. F., Cal.
Mr. C. A. SPRECKELS*.....	San Mateo, Cal.
Mrs. C. A. SPRECKELS*.....	San Mateo, Cal.
Mr. RUDOLPH SPRECKELS.....	2000 Gough St., S. F., Cal.
Miss GERTRUDE STANFORD.....	{ Warm Springs, Alameda Co., Cal.
Mr. THOS. W. STANFORD*.....	{ 142 Russell St., Melbourne, Victoria.
Dr. JOEL STEBBINS.....	{ University of Illinois, Uni- versity Station, Urbana, Ill.
Mr. C. M. ST. JOHN.....	{ U. S. Custom House, S. F., Cal.
Mr. JULIUS STONE*.....	{ Care of the Ohio Central Fuel Co., Columbus, Ohio.
Prof. I. STRINGHAM, PH.D.....	Berkeley, Cal.
Mr. V. STRÖYBERG*.....	{ Observatory, Copenhagen, Denmark.
Mr. DANIEL SUTER.....	317 Bush St., S. F., Cal.
Mr. C. F. A. TALBOT.....	204 California St., S. F., Cal.
Mrs. LOUIS TAUSSIG.....	2127 California St., S. F., Cal.
Dr. JOHN M. THOME*.....	{ National Observatory, Cor- doba, Argentine Republic.
Dr. S. D. TOWNLEY.....	{ Latitude Observatory, Ukiah, Cal.
Prof. R. H. TUCKER.....	{ Lick Observatory, Mt. Ham- ilton, Cal.
Mr. HENRY J. TURNER*.....	{ Woodville, Rappahannock Co., Virginia.
Dr. OMAR A. TURNEY.....	{ U. S. G. S., Livingstone, Gila Co., Arizona.
Mr. FELIPE VALLE.....	{ Director National Observa- tory, Tacubaya, Mexico.
Mr. EDWARD H. VAN INGEN.....	9 East 71st St., New York, N. Y.
Mr. F. W. VAN SICKLEN.....	{ 1831 Central Ave., Alameda, Cal.

Dr. W. VILLIGER.....	Jena, Germany.
Mr. W. R. WARNER.....	{ Care of Warner & Swasey, East Prospect St., Cleve- land, Ohio.
Dr. W. SEWARD WEBB.....	{ 51 E. 44th St., New York, N. Y.
Mrs. W. SEWARD WEBB.....	{ 680 Fifth Ave., New York, N. Y.
Prof. Dr. L. WEINEK.....	{ Imperial Observatory, Prague, Austro-Hungary.
Mr. CHAS. J. WELCH.....	{ The Royalton, 44 W. 44th St., New York, N. Y.
Dr. ANDREW D. WHITE*.....	Ithaca, N. Y.
Mr. E. J. WHITE, F.R.A.S.....	{ Observatory, Melbourne, Vic- toria.
Mr. A. STANLEY WILLIAMS, F.R.A.S....	{ 20 Hove Park Villas, Hove, Sussex, England.
Mrs. MARY H. WILLMARTH*.....	222 Michigan Ave., Chicago, Ill.
Mr. RUSSELL J. WILSON*.....	2027 California St., S. F., Cal.
Colonel B. WITKOVSKY*.....	{ St. Petersburg, W. O. 9th line, 44, Russia.
Mr. J. H. G. WOLF.....	92 Flood Building, S. F., Cal.
Mr. FREDERICK W. ZEILE*.....	{ Mercantile Trust Co., S. F., Cal.
Prof. C. V. ZENGER, F.R.A.S.....	Smichow, Prague, Bohemia.
Mr. F. R. ZIEL.....	308 California St., S. F., Cal.

LIST OF CORRESPONDING INSTITUTIONS.

Albany, New York, Dudley Observatory.
 Allegheny, Pennsylvania, Allegheny Observatory.
 Armagh, Ireland, Armagh Observatory.
 Berlin, Germany, Königl-Astronomisches Rechen Institut.
 Berlin, Germany, Royal Observatory.
 Cambridge, England, University Observatory.
 Cambridge, Massachusetts, Harvard College Observatory.
 Cape Town, Africa, Royal Observatory.
 Catania, Italy, Italian Spectroscopic Society. Observatory.
 Christiania, Norway, University Observatory.
 Cincinnati, Ohio, University Observatory.
 Cordoba, Argentine Republic, National Observatory.
 Dorpat, Russia, University Observatory.
 Dublin, Ireland, Dunsink Observatory.
 Dublin, Ireland, Royal Dublin Society.
 Edinburgh, Scotland, Royal Observatory.
 Geneva, Switzerland, Observatory.
 Glasgow, Scotland, University Observatory.
 Gotha, Germany, Ducal Observatory.
 Goettingen, Germany, Royal Observatory.
 Greenwich, England, Royal Observatory.
 Hamburg, Germany, Hamburger Sternwarte.
 Helsingfors, Russia, University Observatory.
 Kasan, Russia, University Astronomical Observatory.
 Kiel, Germany, University Observatory.
 Kodaikanal, Palani Hills, South India, Observatory.
 Koenigsberg, Germany, University Observatory.
 La Plata, Argentine Republic, Observatory.
 Leipzig, Germany, University Observatory.
 Leyden, Holland, University Observatory.
 Lisbon (Tapada), Portugal, Real Observatorio.
 London, England, British Astronomical Association, care of F. W.
 Levander, 30 North Villas, Camden Square, N. W.
 London, England, British Museum.
 London, England, Royal Astronomical Society.
 London, England, 3 Verulam Bldgs., Gray's Inn, The Nautical Almanac.
 Lund, Sweden, University Observatory.
 Madison, Wisconsin, Washburn Observatory.
 Madrid, Spain, Royal Observatory.
 Marseilles, France, Observatory.
 Melbourne, Victoria, Observatory.
 Mexico, Mexico, Sociedad Cientifica "Antonio Alzate."
 Milan, Italy, Royal Observatory.
 Moscow, Russia, University Observatory.
 Munich, Germany, Royal Observatory.
 Naples, Italy, Royal Observatory.

New Haven, Connecticut, Yale University Observatory.
New York, New York, American Mathematical Society.
New York, New York, Columbia University Observatory.
Nice, France, Observatory.
Northfield, Minnesota, Carleton College Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Padua, Italy, Astronomical Observatory.
Paris, France, Bureau of Longitudes.
Paris, France, National Observatory.
Paris, France, Rue Cassini 16, Société Astronomique de France.
Philadelphia, Pa., 105 South Fifth St., American Philosophical Society.
Potsdam, Germany, Astrophysical Observatory.
Prague, Austro-Hungary, University Observatory.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Observatory of the Roman College.
Rome, Italy, Specula Vaticana.
San Francisco, California, California Academy of Sciences.
San Francisco, California, Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.
Strassburg, Germany, University Observatory.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, National Observatory.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatory.
Turin, Italy, Observatory.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, Imperial Observatory.
Vienna (Ottakring), Austria, Von Kuffner's Observatory.
Washington, District of Columbia, Library of Congress.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
William's Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, William's Bay, Wisconsin.
Sirius, Cologne, Germany.
The Observatory, Greenwich, England.

FOR REVIEW.

[See *Publications*, A. S. P., vol. VIII, p. 101.]

The Call, San Francisco, California.

The Chronicle, San Francisco, California.

The Examiner, San Francisco, California.

The Mercury, San José, California.

The Record-Union, Sacramento, California.

The Times, Los Angeles, California.

The Tribune, Oakland, California.



RING NEBULA IN *LYRA* (MESSIER 51).

By J. E. KEKLER.

(By courtesy of the Editors of the *Astrophysical Journal*.)

THE RING NEBULA IN *LYRA*.

BY BURT L. NEWKIRK.

(Read before the Astronomical Society of the Pacific, November 28, 1903.)

Soon after sundown at this time of the year a bright bluish star may be seen in the northwest sky. It is the star *Vega*, the principal star of the constellation *Lyra*, and the brightest star of the northern hemisphere. The other stars of the constellation are inconspicuous. Near one of the fainter of these stars is situated the Ring Nebula in *Lyra*, the largest and finest of the annular nebulae. (See plate.)

The nebula as it appears in the photograph is oval in shape, somewhat broader and less intense at the ends, and contains a star in the center. A careful examination of the original negative shows that what appears here as a plain ring devoid of fine detail is really a composite structure showing interlaced streamers of nebulosity.* As seen in a telescope of ten inches aperture, the ring is large and bright, but the central star, which is so conspicuous in this photograph, and indeed in all photographs of the nebula, is visible to the eye only with the help of two or three of the largest telescopes in the world. Mr. BARNARD says that it is a very difficult object with the great telescopes of the Lick or Yerkes observatories. The ease with which this star, so difficult to see, can be photographed is due to the fact that its light is composed largely of waves from the violet region of the spectrum, which affect the photographic plate more strongly than they affect the retina of the eye. A longer exposure than that given the plate from which this reproduction is made shows the ring to be entirely filled with faint nebulosity. Professor SCHAEBERLE† has recently made some photographs of the nebula, from a study of which he concludes that it is really a spiral nebula, and that the ring-like appearance is due simply to the fact that the wisps of nebulosity which characterize the spiral are too faint and closely wound to be observed ordinarily. If this opinion of Professor SCHAEBERLE'S is confirmed, it will be an important contribution to the subject of nebular forms and the study of the typical life-history of nebulae, as I shall show later.

* KEELER, *Astroph. J.*, Vol. X, p. 193.† SCHAEBERLE, *A. J.*, Vol. XXIII, p. 109 and 181.

Photography enjoys peculiar advantages in its application to the study of the structure of nebulae, as compared with visual methods. It is safe to say that no eye has seen so much of the detailed structure of this nebula by direct visual observation as appears in the photograph of which this is a copy, taken with the Crossley reflector of the Lick Observatory by the late Director KEELER.

One who would gain a definite conception of the position this nebula occupies in the society of the heavens and its relation to the great plan of the universe must answer to himself the following questions: Where is it located? What are its physical characteristics and its composition? What has its life-history been, and what vicissitudes is it destined to undergo in ages to come?

First, where is it? How far is it from our Sun and his family of planets? Is its distance from us comparable to the distances of the stars, or is it immeasurably more remote, or is it perhaps a very near neighbor of ours? We shall see that it is in fact one of our celestial neighbors.

An investigation of the distance of a heavenly body is called a parallax determination. So far as I know, no nebula except this one has been made the subject of a successful parallax determination;* and of all the nebulae of the skies the Ring Nebula in *Lyra* offers the most inviting opportunity to one wishing to determine a nebular parallax. It is the largest of the ring nebulae, which fact gives countenance to the suspicion that it is nearer us than the average. The apparent size of a celestial object as seen from the Earth depends upon two things; its actual size and its distance from us. Since the Ring Nebula appears larger than other nebulae of its class, it is then either actually larger than the other nebulae or nearer to us than they are. Either alternative is, *a priori*, as probable as the other, and if the latter holds it would favor the choice of this nebula for a parallax determination, because the fact is that most celestial objects outside the Sun's system are so far away that their parallaxes are immeasurably small. Certainly not one star or nebula in a thousand has a parallax as large as a tenth of a second, and the usual result of a parallax investigation is simply to show that the object is so far away

* YOUNG'S *Manual of Astronomy*, 1902, § 604.

that its distance cannot be measured with the accuracy at present attainable. In choosing an object for a parallax investigation we ought therefore to fix upon one which we have reason to believe is nearer than the average if we hope for anything but a negative result. This is the only one of the nebulae, with perhaps one exception, that has been found to show evidence of proper motion. Its proper motion tends to confirm the hypothesis of the proximity of the nebula. The relation between proper motion and parallax has been explained by Professor NEWCOMB* in a recent number of the *Astronomical Journal*. Moreover, the central star of this nebula offers a point of vantage for accurate micrometric measurement. This is a very great advantage, inasmuch as the indefinite and hazy character prevalent among nebulae renders the refined measurements necessary for parallax determination practically impossible.

The investigation of the parallax of the central star of the Ring Nebula in *Lyra*, to which I have referred,† differs from other determinations of parallax only in the number of comparison-stars used, in the symmetry of their positions, and in a consequent simplification of the process of reduction of the measures, accompanied by a gain in accuracy. Instead of taking four to six such comparison-stars, as is generally done, sixteen were chosen. It was possible to measure sixteen distances on the photographic plate and carry through the reduction for the whole sixteen, with an increase of labor which was slight in comparison with the advantage gained in the precision of the result. The stars chosen were all faint and differing little in magnitude from the central star of the nebula. They were arranged in eight pairs, and the two stars of each pair were situated at about equal distances from the nebula star and in opposite directions. This symmetry of the position of the comparison-stars made possible the use of the short method of reduction mentioned above, making it unnecessary to apply special corrections for aberration or refraction, which effects a great saving of labor. Moreover, only three of the eight pairs of comparison-stars were chosen in the line of the major axis of the parallactic ellipse. There was a marked advantage in the diversity of the position-angles of the remaining pairs, as

* *A. J.*, Vol. XXII, p. 165

† Dissertation, University of Munich, 1902 (B. L. NEWKIRK).

this made it possible to investigate certain possible sources of error. The result was a parallax of about one tenth of a second, with a probable error of about one eighth of that amount, and an annual proper motion of fifteen hundredths of a second. That is, the radius of the Earth's orbit, as seen from the star, subtends an angle of one tenth of a second, or this star is about thirty-three light-years distant. If this central star actually forms a part of the nebula, and is not, as some have suggested, a star far this side of or far beyond the nebula, which merely happens to be projected upon the nebula as we see it,—supposing, I say, that this star is a part of the nebula, then we may say that the *nebula* is about thirty-three light-years away from us; i. e., it would take light thirty-three years to come to us from the nebula, traveling at the rate of one hundred and eighty-six thousand miles per second. Inasmuch as the great majority of the stars and nebulae are certainly hundreds, and even thousands, of light-years away, we are justified in regarding the Ring Nebula in *Lyra* as one of our nearest celestial neighbors.

Knowing the distance of the nebula, and having the measures of its apparent dimensions as seen from the Earth, we can form an estimate of its actual size. Its longest diameter is about forty seconds,* which corresponds to an actual distance of four hundred times the radius of the Earth's orbit, or fourteen times the radius of *Neptune's* orbit. The smallest radius of the inside of the ring is fifteen seconds, corresponding to a distance equal to five times the radius of *Neptune's* orbit. Thus the whole of the solar system could be put into this ring and would have plenty of room to spare. I am speaking now, of course, of the ring of bright nebulosity shown in the picture. It has already been noted that longer exposures show the ring to be entirely filled with faint nebulosity.

It is to be presumed that the law of gravity holds there as it does in the solar system, and in that case the nebula may be in rotation about an axis coinciding with the axis of the ring, though this is not necessarily the case. This rotation would undoubtedly be very slow. How long it would take to accomplish a complete revolution cannot be stated without knowing the mass of the ring and of the central star, but we

* KEELER, *Astroph. J.*, Vol. X, p. 193.

might surmise that something like three thousand years would be required.* It must not be supposed that the whole ring rotates as a rigid body. This could not be the case. The particles composing the ring move about with a good deal of freedom, each in its own orbit, with occasional collisions, much as do the discrete pieces composing *Saturn's* rings.

The result of the determination of proper motion would lead us to believe that the Ring Nebula is moving along through space with a component of velocity perpendicular to the line of sight of about five miles per second, which is only about one fourth of the average stellar velocity.

It might be objected that this measurement of the distance does not apply to the nebula at all. It is not the nebula whose distance from the Sun's system has been measured, but the central star, and we have no conclusive evidence that the star belongs to the nebula. It might, as hinted at a moment ago, be some star a long distance from the nebula but in line with it as seen from the Earth, so that it only appears to be in the center of the nebula. In answer to this objection it can be urged that it would certainly be a very curious coincidence if this were the case. It would not be at all likely that a random star, having no connection with the nebula, would be so situated as to appear to us to be exactly in the center of the ring. I say it would be a curious coincidence if this were to occur in a single case, but much more so if it were to occur in a number of instances. There are other smaller nebulae of the annular type, and most of these show faint stars in the center. Observers of experience† seem to think that all annular nebulae have these central stars, only their faintness rendering them invisible in some instances. This alone is very convincing evidence in favor of the view that the central star of the Ring Nebula in *Lyra* is actually a part of the nebula. There is, however, corroborative evidence in the fact that an examination of the color of the central star shows it to be of a somewhat greenish tint, which color characterizes nebulae rather than stars. Until very recently there was no instrument in existence with which the spectrum of this central star could be investigated with any

* Period of a satellite revolving about a body of five times the Sun's mass at a distance twelve times the semimajor axis of *Neptune's* orbit.

† BURNHAM, *Lick Obs. Pub.*, Vol. II, p. 159.

degree of accuracy, and so, for want of a better method, Mr. BARNARD adopted the following program.* He carefully focused the forty-inch telescope of the Yerkes Observatory on different stars and took the readings of the focal micrometer in each case. He found that for white stars the readings were all about the same, but there was a marked difference in the reading of the focal micrometer when the telescope was focused upon a gaseous nebula. As light of different colors comes to a focus at different distances from the lens, this was a rough method of testing the color or spectral character of the object pointed at. Then Mr. BARNARD pointed at the central star of the Ring Nebula in *Lyra* and focused carefully. He obtained the following results from the readings of the focal micrometer (the results are given in fractions of an inch): Neb.-Nuc., $+0.20$; Neb.-star, $+0.30$; Nucleus-star, $+0.10$. This shows that the light of the central star differs from the light of an ordinary white star in partaking somewhat of the nature of the light of the nebula. At the time of his death, Professor KEELER was planning to adapt the Crossley reflector to the spectroscopic study of very faint stars, and he had particularly in mind the central star of the Ring Nebula in *Lyra*. This work has been carried forward under the direction of Professor CAMPBELL, and some results recently published by Mr. PALMER, of the Lick Observatory staff. Mr. PALMER† has found it possible to photograph the spectrum of the central star, which he finds to be continuous in that part of the spectrum where the bright lines of nebular light occur. This is not decisive evidence in favor of the claim that the central star is a part of the nebula, but it does not militate against the theory, which indeed needs no more evidence in its favor than has already been adduced.

The question as to the physical character and composition of the nebula next demands attention. It is a gaseous nebula. Its spectrum shows bright lines, indicating the presence of hydrogen and some other substance or substances not known to exist on the Earth or in the Sun or in any of the stars. This substance seems to be characteristic of gaseous nebulae, and has therefore been called *nebulum*. The gas of which the nebula is composed is probably in a condition of great tenuity,

* BARNARD, *Monthly Notices*, Vol. LX, p. 255. KEELER, *Astroph. J.*, Vol. X, p. 193.

† *Astroph. J.*, Oct., 1903, p. 218.

like the upper regions of our atmosphere. The cause of its luminosity is a mystery. It is in all probability not due to heat. The presumption is, that the temperature of the nebula is not far above the absolute zero of interstellar space. The upper regions of our atmosphere often become luminous through electrical discharges, and the light emitted by nebulae may perhaps be produced in this way. Sir NORMAN LOCKYER* proposes to account for the luminosity of nebulae upon the theory that they are composed of swarms of meteorites in an atmosphere of hydrogen, and that the meteorites collide frequently, striking fire. There are, however, grave objections to this theory, especially in its application to ring nebulae.

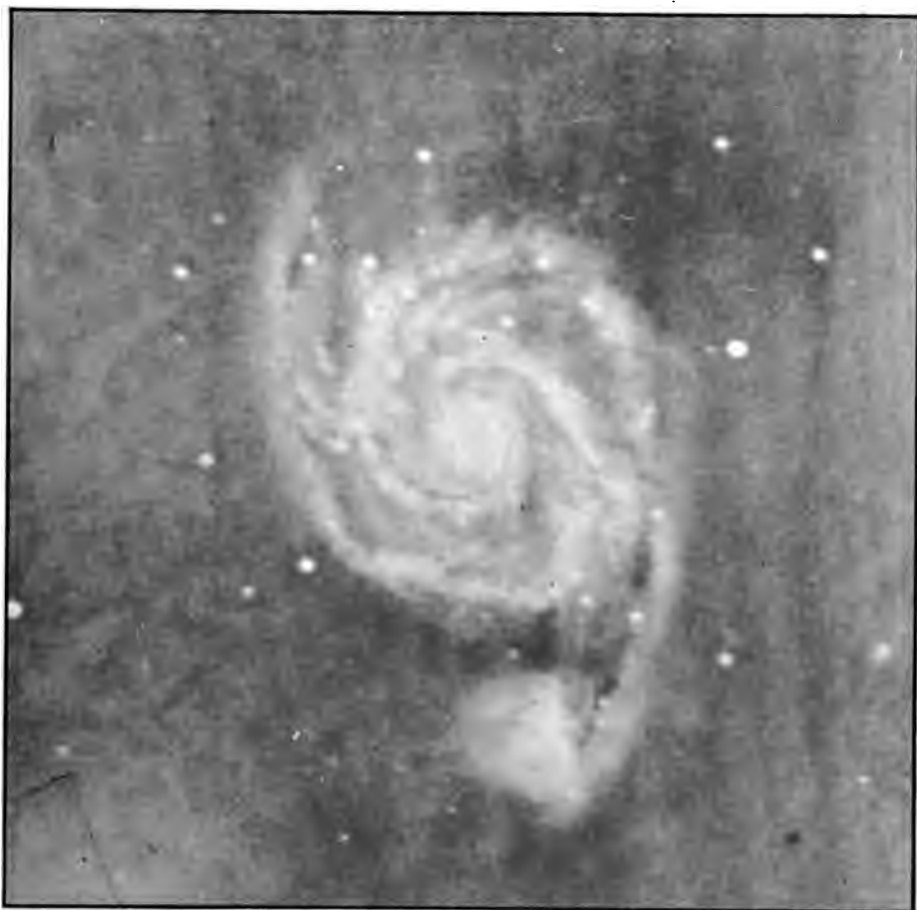
In former times many people believed this nebula to be an immense galaxy of stars. Sir WILLIAM HERSCHEL, who was the first to study nebulae extensively, propounded the theory that all nebulae were clusters of stars very far removed from the solar system, looking like bright clouds in the sky, because his telescope was not powerful enough to enable him to see them as individual stars. Many of the seeming nebulae which he observed in the early part of his life were found later, with the help of a larger and more powerful telescope, to be clusters of faint stars. Thus he concluded quite naturally that a telescope powerful enough would show all nebulae to be star-clusters. Now, stars are suns like the source of our light and heat, and it was the most natural step in the world to the conclusion that our Sun is but one of a galaxy of stars which make up a nebula, and that all nebulae are such collections of suns or stars. It is apparent to any close observer that the stars visible on a clear evening are more thickly crowded together in the neighborhood of the Milky Way, and it is generally believed that our Sun is but one of a galaxy forming an immense ring, or disk, of stars. If one were removed to an immense distance from this galaxy it might look somewhat as the Ring Nebula in *Lyra* looks to us now, but its spectrum would not be that of a tenuous gas; it would be continuous, because the majority of the stars composing the galaxy give continuous spectra. Thus the spectroscope has put an end to such speculation with regard to the Ring Nebula in *Lyra*. It is not a galaxy of stars, but a body of gas at low pressure. In

* Sir NORMAN LOCKYER, *Meteoritic Hypothesis*, MacMillan & Co., 1890.

after life HERSCHEL completely changed his views regarding the composition of nebulae, thereby anticipating the results of modern spectroscopic investigation. He concluded that some of the more whitish of the nebulae really were unresolved clusters of stars, but that many other nebulae about which he detected a greenish tint were masses of gas, which the spectroscope has since shown them to be. The whitish nebulae give continuous spectra, and Professor SCHEINER* has recently found that the continuous spectrum of the spiral nebula in *Andromeda* is crossed by absorption-lines as is the spectrum of sunlight. This does not prove that such nebulae are really galaxies of stars, each of which is comparable to our Sun in magnitude, but it does not disprove it either, and Professor SCHEINER believes this to be the case. He thinks that the spiral nebulae are all systems of stars, like the stars of our Milky Way. If this theory is correct, they must be hundreds of thousands of light-years distant from us.

It is the ringlike shape of this nebula which has brought it into prominence. Presuming that the law of the attraction of gravitation holds there just as it does in the solar system, how can the material composing the nebula assume this ringlike shape? Why does not the whole mass fall toward the center and form a great sphere or spheroid like the Earth or the Sun or one of the planets? It is not enough to assume, as we seemed to a moment ago, in speaking of the rotation of the ring, that this rotation will maintain its equilibrium. I mean to say that we cannot take it for granted that there is any velocity of rotation whatever which would maintain the equilibrium of the ring. The study of figures of equilibrium is one of the most difficult and at the same time the most interesting branches of theoretical astronomy. The problem is this: Given a mass of gas or liquid, each particle of which attracts each other particle, according to NEWTON's law of gravitation, and the whole mass rotating, to find what shape it will assume. In particular, as applied to this case, could a mass of gas rotate with such a velocity that it would assume the shape of a ring? If so, then the ring is a figure of equilibrium. This problem has been discussed by mathematicians of note, among others LAPLACE, MAXWELL, and Madam KOWALEWSKI.

* SCHEINER, *Himmel und Erde*, Vol. XI, p. 325.



MESSIER 51 IN *CANES VENATICI*.

By J. E. KEELER.

MADAM KOWALEWSKI has answered the question in the affirmative. She has shown that a mass of rotating gas or fluid may take the shape of a ring and maintain this shape, unless disturbed by some external force. It is probable, however, that such a ring of gas could offer very little resistance to an external disturbing force; and as such forces certainly do exist and act upon the nebula, it is possible that in a comparatively short time it will gradually break down and assume some other shape, perhaps spherical. In a comparatively short time, I say; but this does not mean a few weeks or a few years, but rather a few hundred thousand or million years. Such processes go on very slowly, and it is hard to set an upper limit to the time that would be required to effect such a transformation.

Perhaps, however, the explanation of the ringlike appearance is to be looked for in an altogether different direction. Possibly the ring does not rotate at all, and in that case each particle swings like a pendulum from one side of the ring to the other, passing rapidly through the center and lingering at the extremities of the swing as a pendulum does. Thus at any given instant most of the material would be in the ring, since each particle spends most of its time at the extremities of its swing. If this is the case, the ring will be quite stable, and will gradually contract into a compact mass without breaking up.

Many investigations have been undertaken in times past in the hope of detecting changes in the shape or brightness of nebulae, or the motion of the whole or any part of a nebula, but without marked success. Drawings of the same nebula made twenty or thirty years apart differ greatly, even when both drawings are made by the same man; but in almost every case these differences have been found to be due not to changes in the nebula, but rather to changes in the men who made the drawings and in the telescopes with which they worked. Nebulae are in general very hazy and indefinite objects, exceedingly hard to draw correctly, and the same nebula often presents different aspects as viewed in different telescopes. It is not to be wondered at, then, that a comparison of old drawings of any one nebula should show much diversity, but no reliable evidence of any change in the nebula. Professor HOLDEN, formerly Director of the Lick Observatory, has made an exhaustive historical investigation of the Great Nebula in

Orion, and from the mass of evidence which he collects and examines he can only conclude that certain parts of the nebula have changed in brightness, but that no motion has occurred in any part of the nebula.

There is a new instrument which is destined to be very useful in the study of changes which occur in the celestial landscape. It has been recently designed, and is now being made in the Carl Zeiss optical workshop in Germany. It is called the stereo-comparator, and is in principle a carefully and accurately made stereoscope. In the ordinary hand stereoscope we have before us in the frame of the instrument a piece of cardboard upon which are mounted two pictures; and we look with one eye at the one and with the other eye at the other. The stereoscopic effect of depth in the picture is due to the fact that the two pictures before us are not made from exactly the same point of view. They are made simultaneously by two lenses mounted a few inches apart, and when we look at the two pictures in the stereoscope, one with the one eye and the other with the other eye, we get the same perspective effect as if we were looking with our two eyes at the scene of the picture. So sensitive are the eyes to this stereoscopic effect that a distance of a few inches between the lenses of the stereoscope camera suffices to give depth to the picture, making the nearer objects seem to stand out clear in front of those behind. This is the principle of the stereo-comparator. It is an accurately made stereoscope, enabling the observer to look with one eye upon one photographic plate and with the other eye upon the other. The eye detects very quickly slight differences between the two plates and thus a quick and easy comparison may be made of two accurate pictures taken years apart. It is in the study of nebulae perhaps that this instrument is at its best. The flocculent, streamy, or cloudy detail of a nebula which only confuses one who attempts micrometric measures would be especially favorable to the detection of a stereoscopic effect due to proper motion or rotation of the nebula or change in its shape.

The question as to the past history of the Ring Nebula in *Lyra* and the prospects of its future career remain to be considered briefly. Was it always a ring nebula, and will it always retain the shape of a ring, or is this only a transitional form

which has been recently assumed and will soon be abandoned? It is only by a comparative study of the observed forms of existing nebulae that light can be gained on these points. Nebulae present very diverse forms to our view. There are great diffuse nebulae covering many square degrees of the sky and showing no definite outline; there are nebulae of definite but very irregular shape; then there are spiral nebulae, and ring nebulae shading into planetary nebulae by degrees so gradual that one is at a loss to draw a line of classification between the two. Diffuse nebulosity may be regarded as the earliest stage of nebular existence. The mutual attraction of the particles forming the nebula is very slight indeed, and contraction goes on very slowly. It is to be presumed, however, that these clouds are moving through space with velocities comparable with those of the stars: twenty or thirty miles per second. They are the winds of the heavens. The next stage is seen in such a nebula as Messier 8 in *Sagittarius*, which shows a tendency toward condensation. The form is irregular, and the mutual gravity of the particles forming the nebula is evidently not the predominant force. An attempt at condensation seems to have been frustrated, resulting in great irregularity of outline and the tearing asunder of the nebulous mass. The Trifid Nebula * is another case of the same sort. These dark lanes in the nebulosity are very curious. They are due perhaps to a collision of the nebulosity with a star, or rather to a star tearing through the nebula. One might at first imagine that the passage left by a star passing through a nebula would be closed up by particles of nebulosity rushing together in its wake, but this is not the case. It can be proven that the passage cleared by the star while passing through would not become narrower and gradually close up, but would get larger as time goes on. This process would not, however, continue indefinitely, because the attractive force exerted by the star while passing through, though powerful for the time being, is only temporary, and in the long run the effects of the temporary force would be obliterated by other weaker but ever-present forces. Thus it is to be expected that in the course of time these lanes will be closed up. The tem-

* See frontispiece to No. 74 of these *Publications*.

porary and fortuitous forces are now in the ascendency, but in the long run the weak but ever-acting force of the mutual attraction of the particles forming the nebula will gain the ascendency and the mass will assume a more regular form.

In the nebula in *Cygnus* the anarchistic forces seem to be triumphant. The nebula seems to have been struck by a celestial whirlwind and torn to shreds.

In the Great Nebula in *Orion** we see evidence of a cataclysm befitting in its grandeur the magnificence of the stellar universe. Two nebulae seem to have collided, and the débris of the conflict is scattered in the rear of the more powerful as it forces its way onward. The dark opening, somewhat resembling a fish's mouth, contains six stars, which are no doubt responsible for the disappearance of the nebulosity at this point. A dark lane such as we observed in the Trifid Nebula seems to be here in process of formation.

The spiral nebula, Messier 51 in *Canes Venatici*, shows the predominant action of the force due to the attraction of the central mass. One of the last, and perhaps the greatest, of the discoveries made by Professor KEELER was, that a large proportion of existing nebulae have this spiral form.

Next in order comes the Ring Nebula in *Lyra*, and last planetary nebulae.

We have traced the progression from the diffuse formless clouds of excessively faint nebulosity to the more dense irregular masses, and passed to the more regular spiral, ring, and planetary nebula. The slow process of contraction is not always left to take its course undisturbed, but it triumphs in the end.

The Ring Nebula may have been evolved from a spiral, or it may be a coördinate form, developed under more peaceful circumstances, where the force of the mutual attraction of the particles is not interfered with by disturbing influences from the outside. Perhaps the amount of rotational energy contained in the original mass is the deciding factor, slow rotation being favorable to the formation of a ring and rapid rotation favoring the spiral form. Professor SCHAEBERLE's conclusion, that the Ring Nebula in *Lyra* is a closely-wound

* See frontispiece to No. 66 of these *Publications*.

It was designed to have a series of seven plates to illustrate the nebulae referred to by Dr. NEWKIRK, but to our regret circumstances beyond our control made this impossible.—THE EDITORS.

spiral, has an important bearing on this point. However this may be, it is certain that the ring form is one of transition which will some day give place to one more stable. In ages to come the material composing the Ring Nebula in *Lyra* will gather itself together into a central sun, accompanied perhaps by a family of planets, and thus become a mature member of the family of the universe.

ASTRONOMICAL OBSERVATIONS IN 1903.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

Z Cygni. *

Jan.	1: Z a little < a.	Feb.	25: a little > c.
	4: midway between a and b.	May	27: invisible.
	8: one step > b.	Aug.	17: { > d. < c.
	19: = a.		21: almost = c.
Feb.	1: = b.	Sept.	12: = b.
	{ < b.		23: = a.
	{ > c.		29: id.
	20: id.	Oct.	20: a little > a.
	22: id.		

S Ursæ majoris. †

Jan.	1: S midway be- tween e and f.	March	29: id.
	4: two steps < e.	Apr.	2: = d.
	8: id.		9: id.
	13: one step < e.		14: id.
	19: id.		22: two steps < e.
Feb.	1: { > e.	May	27: = g.
	{ < d.	Aug.	17: three steps < e.
	15: id.		21: id.
	20: id.		22: two steps < e.
	22: = d.	Sept.	10: one step > e.
	25: one step > c.		12: id.
March	1: one step > d.		19: one step < d.
	22: { > d.		23: id.
	{ < c.		25: id.
	24: id.		29: id.
		Oct.	18: = d.

* Vide the sketch in the *Publications A. S. P.*, No. 48, p. 69.

† Vide the sketch in the *Publications A. S. P.*, No. 73, p. 56.

T Ursæ majoris. *

Jan.	1: three steps > a.	Apr.	2: = f.
	4: id.		14: < g.
	8: id.		22: invisible.
	13: id.	May	27: id.
	19: id.	Aug.	17: one step > f.
Feb.	1: = a.		21: = e.
	15: { < a.		22: one step > e.
	> b.	Sept.	10: one step > b.
	20: = b = c.		12: id.
	22: a little < c.		19: one step < a.
	b = c.		23: = a.
	25: id.		25: id.
March	1: { < c. } b = c.	Oct.	18: id.
	> d. }		
	22: two steps > e.		
	24: id.		
	29: { < e.		
	> f.		

N. B.—Feb. 20–Mar. 1, inclu., was noted $b = c$; in the BD, $b = 8.3$ mag.; $c = 8.5$ mag.

Nova Persei.

	h.	m.		h.	m.
Jan.	1.....	9½ P.M.	9.2	Apr.	2..... 9 P.M. 9.6
	4.....	6	9.2		14..... 9½ 10.0
	8.....	6½	9.2		22..... 9½ 10.0
	19.....	7	9.4	Aug.	16..... 10 10.1
Feb.	1.....	8	9.6		21..... 9½ 10.2
	15.....	8	9.6		22..... 9½ 10.0
	20.....	8	9.3	Sept.	12..... 8½ 10.2
	25.....	8	9.6		19..... 9 10.0
Mar.	1.....	9	9.6		23..... 9 10.0
	22.....	8	9.6		25..... 8 10.0
	29.....	9½	9.6	Oct.	20..... 7½ 10.0

In the last two months no observations could be made on account of change of abode and removing of the observatory to another place in the town.

* *Vide* the sketch in the *Publications* A. S. P., No. 22, p. 63.

FIREBALLS.

In the past year twelve fireballs have been seen from stations in Denmark and surrounding countries, as follows : *

No.	Time.	Beginning.	End.	Mag.	Station.	Notes
1	Feb. 16, 6 ^h 38 ^m P. M.	352° + 49°	328° + 17°	♀	Odder.....	A beautiful fireball, turning pale, but suddenly growing up again to a great intensity. Duration, 12 seconds. Also seen in southern Norway.
2	28, 9 36	137° + 20°	195° + 38°	.....	Odder, and several places in Denmark and Sweden.	The green meteor exploded twice, viz., in the positions 155° + 40°, and 180° + 42°. In Malmö (Sweden), where the meteor lighted up the whole region, an observer, who occasionally turned his back to the window, saw the image of the fireball in a polished brass lamp. At some places a loud detonation was heard, and the meteor apparently fell into the Baltic Sea. The flash was seen 300 kilometers away in all directions.
3	May 18, 9 30	.....	NW.	.....	Rinköbing, and several places in Denmark and Norway.	This meteor passed over the North Sea, and left behind a curious turning and winding train, which remained visible for twenty-five minutes.
4	Nov. 19, 6 45	W. SW.	E. SE. 70° altitude.	.....	Kolding.....	The fireball was seen at several stations, where it lighted up the whole region, and consisted of two meteors, a large one and a little one following it.
5	19, 7 55	.....	N. NE.	.....	Hanneke.....	Thin clouds covered the sky, when suddenly everything was lighted up from a shine behind the clouds; the meteor itself was not observed, but sixty seconds after its extinction a loud "thunder" was heard from N. NE.
6	19, 8 45	.....	.....	.....	Sorö.....	A flash lighted up the whole region notwithstanding the misty weather. This is the third large meteor on the same evening.

* The details of the six most interesting of these meteors are here given.

A BRIEF ACCOUNT OF THE OBSERVATORY AT
THAMES, N. Z.(Long., $11^{\text{h}} 42^{\text{m}} 10^{\text{s}}.57$; Lat., S. $37^{\circ} 8' 23''.21$.)

BY J GRIGG.

This observatory was erected in 1884, and contains a $3\frac{1}{4}$ -inch refractor, by WRAY, equatorially mounted. a $1\frac{1}{4}$ -inch transit, by LATIMER CLARK, with mean-time and sidereal clocks; also a few subsidiary instruments.

The observations hitherto made include transits, eclipses, occultations, sun-spots, comets, and nebulae. Photographic records were also made for a few years, but afterwards discontinued as regular work.

Since 1886, every comet visible has been observed, its path recorded, and its orbit investigated.

Since 1894, systematic search has been made for new comets, by sweeping the southwest sky. and the position of every nebulous object met with recorded.

In the latter part of 1894, ENCKE's comet being visible to northern observers, a search ephemeris was prepared for its southern path, by which it was found on February 24 and 25, 1895, its position agreeing very closely with that given in *Observatory*, No. 228, which came to hand two months later. So far as the writer knows, these were the only post-perihelion observations made. An ephemeris was afterwards prepared for searching for it on its return in 1898, by which it was found on June 16th, 18^h G. M. T. The information was posted to Sydney, and proved to be the earliest recorded by several days. This was afterwards acknowledged in the *Publications* of the Astronomical Society of the Pacific and the Royal Astronomical Society.

The only new comets hitherto discovered here have been 1902 *c* and 1903 *b*.

The observatory is not yet provided with charts and catalogues of the smaller telescopic stars; hence micrometric measurements can very rarely be made, as the tube of the telescope has to be shifted to the nearest known star for comparison; but it is estimated that, except near the horizon, the apparent

position can generally be ascertained within about two minutes of arc.

November, 1903.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1904.

BY MALCOLM McNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon, March 1, 6 ^h 48 ^m P.M.	Last Quarter, April 7, 9 ^h 53 ^m A.M.
Last Quarter, " 8, 5 1 P.M.	New Moon, " 15, 1 53 P.M.
New Moon, " 16, 9 39 P.M.	First Quarter, " 22, 8 55 P.M.
First Quarter, " 24, 1 36 P.M.	Full Moon, " 29, 2 36 P.M.
Full Moon, " 31, 4 44 A.M.	

On the evening of March 22d the first-magnitude star *α Tauri* will be occulted by the Moon. The occultation will be visible from most parts of the United States, but the exact times vary so that the time for one place does not give much aid in estimating the times for other places. Another occultation of the same star will occur on April 18th, but it can probably not be seen from any part of the country except possibly the extreme west.

There will be an annular eclipse of the Sun on March 16th. The path of the annulus runs from eastern Africa, through the Indian Ocean, Siam, and ends in the Pacific. This is one of the two eclipses of the year. The other will come on September 9th, and will be total solar.

The Sun passes the vernal equinox and spring begins March 20, 5 P.M.. Pacific time.

Mercury is a morning star at the beginning of March, but is too near the Sun for naked-eye observation, rising only about forty minutes before sunrise. It rapidly approaches the Sun, passing superior conjunction and becoming an evening star on the afternoon of March 26th. After that it rapidly increases its distance from the Sun until it reaches greatest east elongation, 20° 12', on the afternoon of April 21st. It then remains above the horizon for an hour and three quarters after sunset, and may be easily seen in the evening twilight. At the end of April it sets about an hour and a half after sunset. The

last two weeks in April give the best chance of the year for seeing the planet as an evening star. It passes only $5'$ south of *Jupiter*, just five hours after passing conjunction with the Sun on March 26th. Unfortunately the proximity of the Sun prevents observation even with a telescope. *Mercury* is in conjunction with *Mars*, $1^{\circ} 16'$ north, on the afternoon of April 8th, and it is barely possible that the two planets may be seen near together on the evening of that day.

Venus is still a morning star, but is moving eastward faster than the Sun, and the two bodies are therefore apparently drawing nearer. On March 1st it rises an hour and one half before sunrise, but by the end of April the interval has diminished to about forty minutes. On account of the superior brightness of *Venus*, the planet can probably still be seen before sunrise, although none of the other planets, except possibly *Jupiter*, could be seen with the naked eye at this short distance from the Sun. It is in close conjunction with *Saturn*, passing $0^{\circ} 20'$ north on the evening of March 7th, and with *Jupiter* on the morning of April 23d, passing $0^{\circ} 30'$ south.

Mars still remains an evening star, but toward the end of the two-months' period it is rather too near the Sun for naked-eye observation. On March 1st it sets about two hours after sunset, and at the end of April less than forty minutes after. As in January and February, the local mean time of setting remains nearly constant, $7^h 36^m$ P.M. on March 1st, $7^h 33^m$ on April 1st, and $7^h 26^m$ on May 1st.

Jupiter is also near the Sun. On March 1st it sets a little more than an hour and a half after the Sun; but the apparent distance between the bodies grows rapidly smaller, and the planet passes conjunction on the morning of March 27th. It then becomes a morning star, and is rapidly left behind by the Sun in their common eastward motion, so that by the end of April it rises about an hour and three quarters before sunrise.

Saturn is also a morning star, rising about an hour before sunrise on March 1st, and at the end of April at a little before 2 A.M. During this time it moves about 5° eastward and a little northward in the eastern part of the constellation *Capricorn*. As seen in the telescope, the rings appear less wide open than when the planet was seen as an evening star during the

early winter, the ratio of minor to major axis being less than one fourth on April 30th. This shutting up of the rings has a material effect in diminishing the brightness of the planet.

Uranus continues to rise earlier, before 3 A.M. on March 1st, and before 11 P.M. on April 30th. It is in the western part of *Sagittarius*, and moves eastward until April 4th, and then moves westward, about half of one degree each way.

Neptune is in the western sky throughout the evening, setting at about 3 A.M. on March 1st, and at about 11 P.M. on April 30th. It is in *Gemini*.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE LALANDE PRIZE AWARDED TO DIRECTOR CAMPBELL.

Comptes Rendus, 1903, December 21st. publishes the following report of Commissioners LOEWY, CALLANDREAU, WOLF, RADAU, JANSSEN, and DESLANDRES, of the Académie des Sciences in awarding to Professor W. W. CAMPBELL the Lalande Prize. This annual prize is awarded to the person who, in France or elsewhere, has "made the most interesting observation, or written the memoir or accomplished the work most useful to the progress of astronomy."

"The commission proposes unanimously to award the Lalande prize to M. CAMPBELL, of the Lick Observatory (California).

"M. CAMPBELL, connected for fifteen years with this observatory, first as astronomer, then as director, has made the best possible use of the great instrument and of the favorable situation of the observatory. Stellar spectroscopy and astrophysics have particularly attracted him, and in this new line of research, he has made important discoveries.

"He has taken up and followed the two principal lines of application of spectrum analysis to the stars, namely the investigation of their chemical composition and physical condition, and the investigation of their radial velocity.

"To him we owe the most thorough study of the numerous remarkable temporary stars of recent years; he has been able to follow to the last stages of their decline the most difficult for observation and to recognize their more or less complete transformation into nebulae.

"He has also been largely occupied with the spectra of variable stars and of numerous stars exhibiting individual

* Lick Astronomical Department of the University of California.

peculiarities; he has found a great number of stars which contain in their spectra both bright and dark lines from the same origin, and which thus form in a sense an entirely new type.

"In the investigation of radial velocities his work is important. He has discovered about thirty spectroscopic binaries—a larger number than discovered by any other observer. One of these has such variations of radial velocity as to indicate two periods, and is therefore a triple system.

"In this time he directed one of the American expeditions sent to the Indies to observe the total solar eclipse of 1898. The results obtained regarding the spectrum and rotation of the solar corona are of the greatest interest.

"These many works assure M. CAMPBELL one of the first places among modern astronomers.

"The conclusions of this report are adopted by the Academy."

THE NEW YEAR'S TIME-SIGNALS FROM WASHINGTON, D. C.

The series of time-signals sent from the U. S. Naval Observatory throughout the United States at the beginning of the year created no little interest.

The standard clock of the observatory was connected by wire with the local telegraph-office and the beats of the clock were transmitted to all parts of the country. The electric connections of the clock are such as to omit certain seconds, enabling any one listening to a sounder to recognize the beginning of each minute and especially the first minute of the hour. The five seconds preceding the beginning of the minute are omitted, and for the beginning of the hour the ten seconds preceding are omitted. Hence the observer listening to the sounder is enabled to identify the hour, minute, and second of the Naval Observatory clock and compare it with his own.

The time-signals were received at this Observatory by telephone from the sounder in the Western Union office at San José at ten, eleven, and twelve o'clock, and a comparison made with the beats of a sounder electrically connected with our own standard clock. It so happened that the standard clock at this place was exactly correct at midnight, so that in making a comparison no correction was needed. At ten o'clock and

eleven o'clock the comparisons were made by listening to both sounders—one through the telephone-receiver, the other in the telephone, both beside the observer. The sounders beat very nearly together, but it was thought that the Washington clock beat about $0^s.05$ after our own clock.

At twelve the two clocks were compared upon a chronograph—the observer in the telephone booth hearing only the beats of the Washington clock and recording them by breaking an electric circuit connected with the chronograph. The chronograph-sheet was read later, and for a series of twenty consecutive records showed the Washington clock to beat $+ 0^s.047$ later than our own.

It is proposed by the Naval Observatory to send out such signals each New Year, and no doubt, as people become familiar with the custom, a great deal of interest will be taken in the matter.

NOTE ON COMET BROOKS.

My observations of this interesting short-period comet from the date of its rediscovery, August 18, 1903, to October 24, 1903, are published in *Lick Observatory Bulletin*, No. 49. During this period the comet's brightness diminished rapidly, so that on the last date it was very difficult to make measures of it even with the great telescope.

Stormy weather and moonlight prevented further observations until December 10th, when it was found that a marked change had taken place in the comet's appearance. It was brighter than it had been when first observed in August, and had developed a nuclear condensation that was almost sharp enough to be called stellar. As the comet's distance from the Earth had meanwhile increased by nearly seventy millions of miles, this change must be credited to the internal activity of the comet, doubtless due to its passage through perihelion early in December.

An observation secured on January 15, 1904, shows that the comet will probably remain visible until March, if weather conditions are favorable.

R. G. AITKEN.

January 19, 1904.

GENERAL NOTES.

The *Astronomical Journal*, No. 551, contains an article by PAUL S. YENDELL, on "The Light Variations of 320 *U Cephei*." The variability of this star, of the *Algol* type, was announced by CERASKI in 1880, and as there were but five stars of this interesting class of variables known at that time, the announcement attracted considerable attention.

Mr. YENDELL has collected all the observations of this star, —over three thousand altogether,—and has made a very careful discussion of them to determine the form of the light-curve. The magnitudes of the comparison-stars were determined photometrically by Dr. MÜLLER, of Potsdam; and CHANDLER's elements, which were found to represent the observations very closely, were used in the discussion. As an indication of the care with which the investigation has been made and of the refinement obtained in variable-star observations, it might be noted that it was necessary to discuss separately the observations made in the spring and those made in the autumn. A small but appreciable difference is found in the resulting curves, the difference being, in all probability, a subjective rather than a real one, caused by the different relative positions of variable and comparison-stars in east and west hour-angles. It is to be regretted that no photometric observations of this star have been made, because with a properly arranged photometer this subjective effect can be entirely eliminated. It is to be regretted, also, that Mr. YENDELL has not published graphical representations of the curves derived. These help the reader immensely in properly grasping the results of the investigation. Regret number three may be in order at this point. YENDELL's results have been obtained from discussion of the observations of eight persons,—BAXENDELL, senior and junior, CHANDLER, KNOTT, PLASSMANN, SCHWAB, SPERRA, and YENDELL. Only one of the series of observations made by these persons, KNOTT's, and a part of PLASSMANN's, have been published. All of the other observations, fully two thirds of the whole, were transmitted to Mr. YENDELL in manuscript. And so it is, if any one wishes to make an exhaustive study of the light-variations of any variable, it is necessary to send letters all over the world and ask variable-star observers to transmit their

observations. This they are usually very glad to do, but it is easily seen that it would be much better for both observer and computer if the variable-star observations could be published. It is respectfully suggested that this might be an appropriate matter for the trustees of the Carnegie Institution to take under consideration. S. D. T.

The *Astronomical Journal*, No. 553, contains the results of some important investigations by Dr. CHANDLER, being a revision of the elements of his third catalogue of variable stars, published in 1896. All observations *published* since that time have been used in determining the revised elements. An important feature of the tabulation published is contained in the last three columns, which give the number of maxima and the number of minimi that have been used in deriving the revised elements, together with the limiting dates between which the observations were made. The observer can see at a glance which stars are in most need of observation. S. D. T.

The Memoirs of the British Astronomical Association, Volume XI, Part IV, contain the fifth report of the section for the observation of variable stars. The observations were made by about twenty members of the Association, under the direction of Col. E. E. MARWICK, and the present report covers the work done in the three years 1900-1902. The instruments used vary in size from one to twelve inches, the larger instruments being reflectors. The programme included the observation of four variables of the *Algol* type, nine short-period, twenty-five long-period, and eight irregular ones, and a total of 7,450 observations were made. These observations have all been reduced, and the resulting light-curves graphically represented in the memoir, a feature to be highly commended. S. D. T.

In *Monthly Notices of the Royal Astronomical Society*, Volume LXIII, No. 9, there is an important article by Professor WADSWORTH, Director of the Allegheny Observatory, on "The Construction of Telescopes Whose Relative or Absolute Focal Length Shall Be Invariable at All Temperatures." Two chief factors are to be reckoned with in this investigation, —the change in the focal length of the lens combination, and

the change in the length of the telescope tube, and, for practical purposes, the problem will be solved if these two parts of the telescope be constructed of such materials that the change in the one is just compensated by the change in the other. There are three variables at the disposal of the investigator, the density of the crown glass, the density of the flint glass, and the material of the telescope tube. Professor WADSWORTH'S attention was first called to this subject by the peculiar behavior of the new steel-tube meridian-circle of the Naval Observatory. While using this new instrument Professor UPDEGRAFF found an unmistakable change in its apparent focal length with changes of temperature; and it now appears that the amount of the change agrees very closely with that deduced by Professor WADSWORTH from the theoretical considerations. It appears, from the investigation, that for the lenses usually used for meridian-circles a brass tube gives almost perfect compensation, but a steel tube does not. It is possible, however, to so vary the glass of the lenses that compensation may be obtained with a steel tube.

It is possible to bring another variable into the investigation, and thus increase the exactness of the compensation, by constructing the telescope-tube of two parts of different materials. This may not be desirable for meridian-circles, but probably not objectionable for equatorials. Professor WADSWORTH suggests one combination of steel and nickel steel.

This subject of changes in focal length is of great importance in all meridian-circle, heliometer, photographic, micrometric, and spectrographic work, and designers of instruments will do well to take heed of the results obtained by Professor WADSWORTH.

S. D. T.

The leading article in the *Astrophysical Journal* for October is one by Dr. HARTMANN, entitled "A Revision of Rowland's System of Wave-Lengths." By way of introduction, Dr. HARTMANN says: "ROWLAND'S system of wave-lengths has become the basis of all spectroscopic measurements made in recent years, and with the progressive increase in the precision of these measures the necessity has now arisen of testing the reliability of that important basis, and, in case it should not appear as adequate, of correcting it by new series of observa-

tions, in order thus to create a foundation sufficient for all demands."

Dr. HARTMANN then goes on to explain the methods used by ROWLAND in determining the wave-lengths of the various tables published by him, concluding that ROWLAND's "Preliminary Table of Solar Spectrum Wave-Lengths" is the most accurate. Even this table, however, according to HARTMANN's investigation, has a small systematic error running through it, but he thinks it is now possible to determine the necessary corrections to ROWLAND's wave-lengths. Special and delicate apparatus will be required for carrying out this work, and HARTMANN suggests that it would be advisable to have these researches carried out independently at a number of places.

S. D. T.

Sir WILLIAM RAMSAY, F. R. S., addressed the British Astronomical Association in London recently on "Some Speculations Regarding Stars and Atoms." In 1878 the French astronomer JANSSEN, and Sir NORMAN LOCKYER, in England, discovered a line in the Sun's spectrum near that which marks the presence of sodium, and, as it was then supposed to indicate an element peculiar to the Sun and unknown on Earth, it was called helium. Sir WILLIAM, by careful search, detected this supposed unknown element in the mineral cleveite. The discovery came most opportunely, for it followed the finding of argon in the atmosphere, and helium belongs to the same class as argon, in being an inert body incapable of forming combinations with others. Since then other similar elements—neon, krypton, xenon—have been identified in the air, and they are of the same inert class. But these elements, especially helium and krypton, seem to afford an alluring link connecting terrestrial physics and chemistry with those of the Sun and stars. One of the speculations on which Sir WILLIAM ventured was, that the action of krypton may explain that hitherto obscure phenomenon, the aurora borealis. There is now reason to believe, as one outcome of the examination of radio-active bodies, that the Sun not only sends out rays of light and heat, but is also continually projecting into space corpuscles of electrified matter which electrify the regions of the upper atmosphere. It has long been thought that the aurora was an

electrical phenomenon. Its radiant arch and brilliant streamers give this impression naturally. The problem was to identify the constituent of the atmosphere which was the subject of the electrifying action. Professor RAMSAY believes that he has discovered that constituent in krypton. In the ocean of air above us a ceaseless circulation is going on between the tropics and the polar regions, the heated air of the equatorial zone flowing northward at a great elevation, while the polar currents return at a lower level to the tropics. There is cause for thinking that krypton, though a heavy gas, ascends to the higher regions, because the element, being monatomic, would be more powerfully affected by tropical heat than elements like hydrogen and oxygen, made up of molecules of two atoms. And in those upper regions of the air we can suppose that it is electrified by solar corpuscles, and, becoming denser in the polar circle, gives out the aurora discharge. More than this, Sir WILLIAM showed that in a laboratory experiment with air in a globe containing krypton an auroral light can be produced. Moreover, the spectrum of the aurora and of krypton appear to be identical. Having described the discovery by BECQUEREL of the principle of radio-activity, and the isolation by Madame CURIE of the most wonderful example of that principle with radium, Sir W. RAMSAY explained the three species of radiations from radium,—the *alpha* rays, which are easily stopped; the *beta* rays, which are more penetrating (these two being material corpuscles charged with electricity); and the *gamma* rays, which will go through several inches of lead, and are undulations of ether resembling those of light or electricity. Besides these was the emanation of a heavy gas leaving a residuum, which he and Mr. SODDY had proved to be helium. Professor J. J. THOMSON had made it probable that the corpuscles given off by atoms were electrons, the *alpha* rays being positively and the *beta* negatively electrified; and they could conceive of an atom as a system in which a large number of small bodies might be revolving round a center.

Dr. JOHNSTONE STONEY had pointed out that there was probably a natural limit to the size of the suns and stars. When a sun exceeded a certain volume a portion of its mass would be thrown off. So it might be with the atom. In uranium and radium they had the heaviest known elements,

and these, passing the natural limit of atomic dimensions, might be throwing off the electrons which in the case of radium produced such marvelous effects.—*Extract from the Scotsman.*

Harnessing the Dog Star.—A French astronomer, M. TOUCHET, who has previously photographed objects by the light of *Venus* and *Jupiter*, has now succeeded in obtaining a photograph by the light of *Sirius*, the most brilliant of all the stars. An ordinary camera was used, but the customary objective was replaced by a cardboard tube, to the end of which a small brooch, the object it was intended to photograph, was affixed. The light of the star was concentrated upon the brooch through a powerful lens, and the exposure lasted an hour and five minutes. The result was an admirable photograph of the star with a clear reproduction of the brooch in its center. When it is remembered, says the *Debats*, that *Sirius* is ninety-two trillion of kilometers from the Earth, and that its light takes nine years and nine months to reach us, the rays which permitted the photograph to be taken must have been traveling through space since 1894 at the tremendous rate of 187,500 miles per second.—*Dalziel, London Daily Graphic, Dec. 5, 1903.*

A Royal Medal of the Royal Society has been awarded to Sir DAVID GILL, K. C. B., F. R. S., for his researches in solar and stellar parallax, and his energetic direction of the Royal Observatory at the Cape of Good Hope.

It is reported that among the subjects now under consideration by the Carnegie Institution in connection with grants are a solar observatory, a southern observatory, a geophysical observatory, and the establishment of international magnetic researches.

Transit-room shutters of a new design by Professor D. P. TODD were erected the last week in November at Amherst College Observatory. They were built by the Coburn Trolley Track Company and the Norton Iron Works, with special reference to ease and rapidity of working.—*Science, Dec. 18, 1903.*

Our amateur astronomers may be interested in the brief description, in the January number of *Popular Astronomy*, of a fourteen-foot dome built by one of our members, Mr. C. F. HARMS, of Brooklyn, N. Y. It is a good solution of the problem to attach to a residence, at a reasonable cost, a dome answering all reasonable demands.

Mr. ANDREW GRIEG sends us the following interesting extract from the *Scotsman*: "In a recent lecture on 'Other Worlds than Our Own,' Sir ROBERT BALL said we were most interested in our next-door neighbors, *Venus* and *Mars*. With regard to *Venus*, the Professor accepts as proved the theory on which Mr. WALLACE relies, that it always turns the same face to the Sun, so that one hemisphere has perpetual night, and the other unending day. He did not think that *Venus* was now the habitation of rational beings. Life there might be, but scarcely that of sentient beings like ourselves. Looking at the scores of millions of years of this world's existence, and the fact that 100,000 years would be a liberal estimate for human history, it seemed scarcely likely that rational life on *Venus* would be simultaneous with that here.

"For various reasons Sir ROBERT was inclined to think that no other planet of the solar system is likely to be inhabited at present by creatures like ourselves. In some the time is past; in others it may be yet to come. In time past the Moon may have been inhabited, but no distinct trace of atmosphere is now found, and its seas seem to have sunk into the cavernous interior, as most probably some day the Earth's seas will do.

"Professor BALL dismisses the canals of *Mars* as optical illusions, and is disposed to believe that we see few if any seas on its surface, but rather certain areas capable of supporting vegetation, and others desert. The pictures of *Jupiter* seemed to suggest that the planet was still too hot to be peopled—not through the Sun's heat, for that was only one twentieth of what we received—but in consequence of *Jupiter's* own high temperature as a cooling globe. What water exists is most likely not on the planet's surface, but is carried as vapor in its vast atmosphere. A succession of lime-light pictures was thrown on the screen to emphasize the transcendent grandeur of the stellar universe, and the countless number of worlds

which it must contain. We see only the suns and bright nebulæ, but the dark unseen worlds were almost certainly many times more numerous. While rejecting the idea of an infinite universe with an infinite number of suns,—because then the firmament would be a blaze of light,—he enforced the thought that the whole of this group of worlds had a greater design than merely to teach man his insignificance, and that it was reasonable to suppose as there were suns vastly greater than ours, so there were many 'other worlds than ours,' some of them inhabited by beings of far greater capacities."

THE MOON: A SUMMARY OF THE EXISTING KNOWLEDGE OF OUR SATELLITE. With a complete Photographic Atlas. By WILLIAM H. PICKERING, of Harvard College Observatory. One hundred illustrations. New York: Doubleday, Page & Company, 1903. Price, special net, \$10.00.

Although the title as given above states that this volume is a summary of the existing knowledge of our satellite, the author in the first sentence of his preface says, "It is intended in the present volume to give an account of some of the more recent advances in our knowledge of the Moon, leaving to the text-books a statement of the information that was earlier acquired." In point of fact the volume is chiefly devoted to the results of Professor PICKERING's personal selenographical studies, particularly those made in Jamaica in 1901, touching upon other matters in the earlier chapters only so far as necessary to a better understanding of those observations.

One chapter, however, headed "Fancies; Apparent Size; Superstitions; Influence on the Weather," is added that has no particular bearing on the subject-matter of the rest of the volume, and is apparently introduced to make the work more "popular."

It is impossible at the present time to review this work critically. Such a task may more properly be undertaken by one who has made a specialty of selenography. It is my purpose merely to give a very brief account of the author's views, which in some respects are unusual and not as yet accepted by astronomers generally as fully substantiated.

The first point to attract attention is the claim made that any station situated near the equator possesses superior atmospheric conditions for astronomical work. Reading the preface, one would gather that nearness to the equator was the necessary and sufficient condition for a "steady" atmosphere, whether the station be located on an island or high up among lofty mountains. From such a location the author claims that a twelve-inch telescope will show planetary details invisible in the largest telescopes of this country and Europe. "What is now needed," he adds, "is a large telescope located near the equator, but just how near it is necessary or desirable to go has not as yet been definitely determined."

Passing on to the text, we find that the opening chapters treat of "The Moon's Origin; Its Relation, Distance, Orbit," etc. Then follow chapters on its Atmosphere and Temperature; the Origin of Lunar Craters, with an account of some miniature craters formed experimentally; Active Lunar Craters; Ice on the Moon; Vegetation and the Lunar Canals; and Recent Investigations. These chapters deal principally with Professor PICKERING's own observations, and the theories he has framed to interpret them. Then comes the chapter on "Fancies," etc., already mentioned, which in turn is followed by an account of the formation and arrangement of the photographic atlas of eighty plates, which, with a good guide-map, concludes the volume.

We find that Professor PICKERING agrees with astronomers generally in believing that the density of the Moon's atmosphere "does not exceed the one ten-thousandth part of our own." But he thinks that we have positive evidence that a very tenuous atmosphere does exist on the Moon and that it is "a factor in selenography by no means negligible." Since he agrees with other investigators in thinking that our ordinary atmospheric gases—oxygen, nitrogen, and in fact all gases, except perhaps the very heavy ones, like carbonic acid—would probably have escaped from the surface of the Moon long ere this, he finds the source of the present lunar atmosphere in gases "constantly renewed from the Moon's interior." "Let us now see," he proceeds, "what gases are at the present time being given off from the Earth's interior. We find that there are only two that escape in large quantities—carbonic acid and

water-vapor. The former would remain for some time on the Moon's surface on account of its weight, and the latter because on account of the low pressure the rapid evaporation would cause it immediately to freeze."

Here we have at once the origin of the Moon's atmosphere, and of the "snow," or "hoar-frost," of which a great deal is said in the later chapters.

The discussion of the origin of the lunar craters and the account of miniature craters observed in cooling slag-iron, and others artificially formed from cooling paraffin, are very interesting, and will leave little doubt in the minds of most readers that the source of the lunar craters was volcanic activity.

The following chapters are devoted to the discussion of gradual changes that various observers have noted in such craters as *Linné* and *Plato*, and many changes, observed by Professor PICKERING himself, which differ from those noticed earlier, in being periodic, the periods depending on the alternation of the lunar night and day. The explanation of most of these periodic changes the author finds in the exuding of water-vapor from crevices in the Moon's surface, its freezing during the lunar night and its consequent deposit in the neighborhood of the crevices as "hoar-frost," and its more or less complete evaporation during the lunar day. The author presents detailed evidence, illustrated by drawings and photographs, in favor of the reality of these periodic changes and of the adequacy of his theory as to their cause. As was said in the beginning, it is not our purpose to discuss this evidence here; nor can we examine critically the arguments advanced in favor of the theory that certain "variable spots" that Professor PICKERING sees upon the Moon are due to the coming up, flourishing, and dying of low forms of organic life resembling vegetation. These, and the "lunar canals" are matters that must be left to the expert selenographer. We need only say here that they are not yet accepted by astronomers generally without question.

Whatever may be the final judgment as to Professor PICKERING's observations and theories, there is no question but that the photographic atlas will be found a useful and convenient guide to the amateur observer of the Moon. It is composed of

eighty plates, reproduced without enlargement from as many negatives, which were taken by Professor PICKERING in Jamaica in 1901. His instrument was a twelve-inch lens of 135 feet 4 inches focal length. The Moon's equatorial diameter was divided into eight equal parts and perpendiculars drawn to it, cutting the lunar surface into sixteen areas. Each area was photographed five times, at lunar sunrise, noon, and sunset, and at two intermediate times, designated as morning and evening.

Examination of the atlas indicates that the negatives were generally good, but in many cases they have not been reproduced in a manner altogether satisfactory. Large-scale photographs like those issued by the Lick and Paris observatories are, of course, to be preferred for many purposes, but they are not readily accessible. The present atlas is on a scale sufficiently large for general use, and its completeness and systematic arrangement, together with its full index and its maps, should make it a useful and convenient guide. R. G. A.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE LIBRARY OF THE STUDENTS' OBSERVATORY OF
THE UNIVERSITY OF CALIFORNIA, AT BERKELEY, JANUARY
30, 1904, AT 7:45 P.M.

President VON GELDERN presided. A quorum was present. The minutes of the last meeting were approved.

The following new members were duly elected :—

LIST OF MEMBERS ELECTED JANUARY 30, 1904.

Mr. HERMAN JOHN DAVIS 369 Sutter St., S. F., Cal.

Mr. EDWARD DONOHUE { Donohoe-Kelly Banking Co., S. F.
Cal.

Mr. D. S. GLOVER 2449 Webster St., Berkeley, Cal.

A committee to nominate a list of eleven Directors and Committee on Publication, to be voted for at the annual meeting, to be held on March 26th, was appointed as follows: Messrs. J. D. GALLOWAY (Chairman), J. K. MOFFITT, GEO. L. DILLMAN, WM. GRANT, H. E. MILLER.

A committee to audit the accounts of the Treasurer, and to report at the annual meeting in March, was appointed as follows: Messrs. CHAS. S. CUSHING (Chairman), L. H. PIERSON, D. SUTER.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD IN THE LECTURE HALL OF THE
STUDENTS' OBSERVATORY AT BERKELEY, JANUARY 30, 1904.
AT 8 O'CLOCK P.M.

The meeting was opened by an address of welcome by Dr. BENJAMIN IDE WHEELER, President of the University of California. President VON GELDERN then introduced the other speakers, who delivered the following addresses :—

Opening remarks, by Professor W. W. CAMPBELL.

The Students' Observatory, by Professor A. O. LEUSCHNER.

The Constant of Refraction, by Dr. R. T. CRAWFORD.

The Watson Asteroids, by Dr. B. L. NEWKIRK.

The Photographic Telescope, by Dr. A. F. GILLIHAN.

After the conclusion of the reading of the papers the audience was invited to inspect and use the different instruments of the Observatory.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. OTTO VON GELDERN *President*
 Mr. S. D. TOWNLEY *First Vice-President*
 Mr. W. W. CAMPBELL *Second Vice-President*
 Mr. CHAS. S. CUSHING *Third Vice-President*
 Mr. R. G. AITKEN } *Secretaries*
 Mr. F. R. ZIEL }
 Mr. F. R. ZIEL *Treasurer*
Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CUSHING, LEUSCHNER
 MOLERA, CROCKER, VON GELDERN, PIERSON, TOWNLEY, ZIEL.
Finance Committee—Messrs. PIERSON, CUSHING, LEUSCHNER.
Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.
Library Committee—Mr. TOWNLEY (*Librarian*), Mr. RICHARDSON, Miss O'HALLORAN.
Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
 (February, April, June, August, October, December.)



CONTENTS.

The Network Nebula in <i>Cygnus</i>	<i>Frontispiece</i>
	PAGE
List of Members of the Astronomical Society of the Pacific	1
List of Corresponding Institutions	10
Exchanges	11
Newkirk, B. L. —The Ring Nebula in <i>Lyra</i>	13
Kohl, Torvald. Astronomical Observations in 1903	25
Grigg, John. A Brief Account of the Observatory at Thames, New Zealand	28
McNeill, M. Elementary Phenomena for March and April, 1904	29
Notices from the Lick Observatory	32
General Notes	35
Minutes of the Meeting of the Board of Directors	40
Minutes of the Meeting of the Society	46
Officers of the Society	47

PUBLICATIONS



OF THE

ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI.

NUMBER 95.

1904.

SAN FRANCISCO:

PRINTED FOR THE SOCIETY

1904.

[Entered at Post Office at San Francisco, Cal., as second-class mail matter.]



THE STUDENTS' OBSERVATORY. AT BERKELEY, CALIFORNIA.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, APRIL 10, 1904. No. 95.

ADDRESS OF THE RETIRING PRESIDENT OF THE
SOCIETY, IN AWARDING THE BRUCE MEDAL
TO SIR WILLIAM HUGGINS.*

BY OTTO VON GELDERN.

Another year in the history of the Astronomical Society of the Pacific has passed, and it becomes my pleasant duty, as your President, to review in some manner the aims and the accomplished work of the organization.

It is the object of the Society, and it has always been its object from the time of its founding, after the total eclipse of January, 1889, to foster astronomical science, not only among those who are professionally engaged in such a field of labor, but to awaken an interest for this, the Queen of all Sciences, in any one whose sole purpose in life is not the all-absorbing search after material welfare to the exclusion of everything else.

There can be no more fascinating study than that of the starry heavens; there is nothing around us that appeals so strongly to all the nobler sentiments of the human heart, to all the finer qualities of the human intellect, than a contemplation of the vastness of creation, the multiplicity of the population of space, and the overwhelming thought, What is there behind all this that seems forever destined to be shrouded in the deepest of mysteries? If there is ever a time when a man realizes his own smallness and insignificance it is when on a bright starry night he looks upward into the heavens and beholds the evidences of an endless creation. If this does not start within him an impression of the deepest awe, if it fails to touch his heart, and if it leaves his mind without

* The data for this address are from the Lick Observatory, the library of the Astronomical Society, and the Mechanics' Library.

that indescribable sense of man's dependence, he may indeed be pitied as an unfortunate, and as one who has not realized the ideals which the man of the twentieth century should cherish and foster.

The Astronomical Society attempts to reach such an ideal by awakening within any one an interest in the affairs of the heavens by a means somewhat different from the theologian, but nevertheless with a purpose fully as definite,—and that is, to help make better men and better women by an appeal to their intellect and their nobler faculties.

Our means to spread astronomical knowledge are not only these periodical lectures, but also the publications issued from time to time; the very excellent library; the summer visits to the Lick Observatory, and thereby the occasional touch with the men who devote their lives to this absorbing science.

Another means to help our members in attaining a knowledge of astronomical principles and astronomical methods of work has recently been added to those already mentioned, and I am very glad to take this opportunity of announcing to you that Professor A. O. LEUSCHNER, the head of the Berkeley Astronomical Department of the University of California, will offer exceptional opportunities to our members during the coming Summer Session of the University, for the purpose of giving the amateur astronomers the advantage of acquiring skill in the various modes of observation. He desires me to state to you the following, which I quote from his letter to me:—

“There will be two courses offered by myself during the Summer Session, one of which will largely consist of practical observing with the many fine instruments now available at the observatory. It is my intention to form groups of such persons as may wish to avail themselves of the opportunities extended, and to enable each group to gain experience in one or more fields of observation. For example, some might be particularly interested in variable stars, others in spectroscopy, others in solar observations, others in planets, others in celestial photography, and others in various other observations with the transit instrument, sextant, or equatorials.”

Here is certainly a rare chance for our enthusiastic members to gain a practical knowledge in astronomy, which would be impossible without appliances and without instruments. I think that Professor LEUSCHNER would be interested to hear from any one who may desire to learn the necessary

details under which enrollment for this instruction is made possible.

With this short reference to the work of the Society, I, as your retiring President, congratulate you upon what has been accomplished, and hope that the future may be as bright as I would predict it. There is a field of usefulness before it, and we as members and interested individuals should never lose sight of the ultimate aim and the good mission which the Society has been created to fulfill.

With these heartfelt wishes I retire from my office, to leave it in hands abler than mine. Before doing so, however, there remains another duty to be performed, and I shall ask your indulgence for a short time to allow me to make a few remarks on the accomplished work of one of the great masters of the science that our Society fosters.

The Bruce Gold Medal of the Astronomical Society of the Pacific, founded by the late Miss CATHERINE WOLFE BRUCE, of New York, has been bestowed for the fifth time by the Board of Directors in conformity with the statutes governing the bestowal of this medal.

Those astronomers to whom it has been awarded previously are: SIMON NEWCOMB, of Washington, in 1898;

ARTHUR AUWERS, of Berlin, Germany, in 1899;

DAVID GILL, of Cape of Good Hope Observatory, in 1900;

G. V. SCHIAPARELLI, of Milan, Italy, in 1902.

This time the choice has fallen upon one of the best known of English astrophysicists, one who has probably done more in his particular field of research than any other astronomer, who may be considered as a pioneer in a field that has opened up so many new directions of investigation, leading to results constantly tending to broaden the knowledge and with it the intellectual horizon of man. I refer to the eminent scientist, Sir WILLIAM HUGGINS.

It becomes my pleasant duty to-night to announce to you the unanimous choice of this great man for the honors that lie within our power to bestow.

It is customary that in making a report like this to you a sketch of the life and the work of the medalist be added. Life-histories of eminent men written for purposes of this kind can at best but contain mere references to their labors and prominent achievements, and if in taking a cursory glance

at the results accomplished by Sir WILLIAM HUGGINS in astrophysical science I should omit to mention even some of the most epoch-making discoveries, you will remember that in this particular case there are so many of them that a brief mention of what his labors have led to is all that can be attempted within the frame of an address like this.

WILLIAM HUGGINS was born in London, February 7, 1824. While his early education was received in the City of London School, it is very probable that his mind must have been awakened at a very early age to the realization of scientific fact, so that with his approaching manhood he had a practical knowledge of physical science. Study in microscopy upon animal and vegetable physiology had occupied his time to a considerable extent, and we hear of his becoming a member of the Microscopic Society in 1852.

But astronomy claimed his attention and became his chief pursuit, for in 1856 a private observatory for his studies was completed at Upper Tulse Hill, where he has constantly devoted himself to scientific investigations. At first they were probably confined to the measurements of the positions of celestial bodies, which was the principal work of the astronomer at that time.

Original minds with original thoughts are not likely to follow any prescribed course in whatever pursuit they may be engaged, and so in this case. The master mind must have conceived at once the great possibilities offered to astronomy by the discoveries and researches of KIRCHHOFF and BUNSEN, and when it was realized that spectrum analysis could be applied to the heavenly bodies, that they could be made to speak their own language, or write their own autographs, as it were, then astrophysical science was born, and disclosed an endless expanse of almost virgin soil, from which the human mind has harvested results as unique as they are marvelous.

This was the field of Sir WILLIAM HUGGINS, in which he has labored with ever-increasing success from the year 1862 until the present time. What he has accomplished in this period of over forty years has been the subject of numerous sketches and articles that have appeared from time to time in the scientific journals of the day.

In an address before the British Association our medalist makes this statement:—

"In 1866 I gave before this Association an account of the first-fruits of the novel and unexpected advances in our knowledge of the celestial bodies which followed rapidly upon KIRCHHOFF's original work on the solar spectrum and the interpretation of its lines.

"Since that time a great harvest has been gathered in the same field by many reapers. Spectroscopic astronomy has become a distinct and acknowledged branch of the science, possessing a large literature of its own and observatories specially devoted to it. The more recent discovery of the gelatine dry-plate has given a further great impetus to this modern side of astronomy, and has opened a pathway into the unknown of which even an enthusiast thirty years ago would scarcely have dared to dream.

"In no science, perhaps, does the sober statement of the results which have been achieved appeal so strongly to the imagination and make so evident the almost boundless powers of the mind of man. By means of its light alone to analyze the chemical nature of a far-distant body; to be able to reason about its present state in relation to the past and future; to measure within an English mile or less per second the otherwise invisible motion which it may have towards us or from us; to do more, to make even that which is darkness to our eyes light, and from vibrations which our organs of sight are powerless to perceive to evolve a revelation in which we see mirrored some of the stages through which the stars may pass in their slow evolutionary progress,—surely the record of such achievements, however poor the form of words in which they may be described, is worthy to be regarded as the scientific epic of the present century."

The first researches were made with Professor W. A. MILLER, of Kings College, a chemist of note, who had made a practical application of spectrum analysis for a period of fifteen years. Their results were incorporated in the Report on the Spectra of Stars, sent to the Royal Society in 1863.

We know that starlight in passing through spectroscopic apparatus is severed into its constituent parts. The light is spread out into a band showing the usual prismatic colors. This band is crossed by lines and the spectroscopic problem is to read their meaning. Dark lines indicate to the spectroscopist that the light comes from an incandescent body, but has passed through cooler media,—that is, in its transmission some of it has been absorbed. Bright lines are evidences that the regions from which they hail are hotter than those below them, and an inspection of the star's spectrum may furnish us with valuable information regarding the physical condition of its atmosphere. Furthermore, the exact position of the spectral lines, and the method of measuring them, give a

clew to the existing chemical composition of the origin of the light.

The spectra of many stars had been compared with those of several terrestrial elements, and it was found that they are hot bodies, similarly constituted to our Sun, and containing many of the substances found on the Earth. The spectra of the planets *Venus*, *Mars*, *Jupiter*, and *Saturn* had also been observed, and the results of these observations were made public in 1864. It is stated that the light from the planet *Uranus* was found too faint to be satisfactory for spectroscopic analysis; but an improved telescope in 1871 resulted in certain determinations showing its spectrum to be continuous, so far as the feebleness of its light permitted it to be traced.

While FRAUNHOFER, LAMONT, and DONATI had examined star spectra before, it must be remembered that the work of HUGGINS lay in an entirely different direction. As stated in an article published in *Nature*, by H. KAYSER, in 1891, it was not simply the idea to see lines in the spectra of stars, but their chemical origin had to be determined; and therefore the light-gathering objective prism could no longer be used, but after the method of KIRCHHOFF and BUNSEN a slit and comparison-prisms were employed. Finding this to weaken the spectrum to a great extent, and in order to broaden the point-like image of the star, his resourceful mind, ever ready to surmount difficulties, introduced the cylindrical lens, made for him by BROWNING.

In undertaking comparisons of spectra it soon developed that the data for such purposes were very insufficient, and HUGGINS undertook the labor of recording the position-lines of a great many elements. This work was of immediate value and proved a great success. Referring to that time, he states, in "The New Astronomy":—*

"The observatory became a meeting-place where terrestrial chemistry was brought into direct touch with celestial chemistry. The characteristic light-rays from earthly hydrogen shone side by side with the corresponding radiations from starry hydrogen, or else fell upon the dark lines due to the absorption of the hydrogen in *Sirius* or in *Vega*. Iron from our mines was line matched, light for dark, with stellar iron from opposite parts of the celestial sphere. Sodium, which upon the Earth is always present with us, was found to be widely diffused through the celestial spaces."

* June number of the *Nineteenth Century*, 1897.

He refers to the time as one of great expectation, for nearly every observation revealed a new fact, and a new discovery was made nearly every night. "And yet, notwithstanding," he continues, "we had to record that the inquiry in which we had been engaged has been more than usually toilsome; indeed, it has demanded a sacrifice of time very great when compared with the amount of information which we have been able to obtain."

As the field broadened the problems multiplied; they crowded themselves upon this original investigator, and while the first problem may have been solely this: What are those shining points of light upon the celestial dome?—there soon suggested itself a second one to his fertile brain, which, like a question whispered to him from the depths of space, asked: Whence came they?

In the year 1864 he began his original researches in a hitherto unexplored region,—that of the nebulae. To this day there remains associated in his memory the profound awe which he felt on looking for the first time at that which the eye of man had never seen, and which even the scientific imagination could not foreshow.

The nature of these mysterious bodies was yet unknown; the view that they were parts of a fiery mist out of which the heavens had been slowly fashioned began to yield, based upon more recent telescopic investigations, to the opinion that all nebulae may be capable of resolution into stars. In the "New Astronomy," already referred to, HUGGINS states:—

"According to this view, nebulae would have to be regarded not as early stages of an evolutionary progress, but rather as stellar galaxies already formed, external to our system,—cosmical sand-heaps, too remote to be separated into their component stars."

It remained a question for a long time whether or not the nebulae could be resolved into stars if a sufficiently powerful telescope could be brought to bear upon them.

The result of HUGGINS's investigations revealed a new scientific fact, and his spectroscopic analysis of the nebular light led to one of the greatest triumphs in astrophysics,—that is, that this phenomenon is not the result of crowding together separate and innumerable stars, but that it is accounted for by the presence of a mass of incandescent gas.

It was on the evening of the 29th of August, 1864, that HUGGINS directed his telescope for the first time to a planetary nebula in *Draco*. In speaking of this memorable event, he says: "Picture to yourself to some extent the feeling of excited suspense, mingled with a degree of awe, with which after a few moments of hesitation I put my eye to the spectroscope." It seemed to him as though he were about to gaze into Nature's secret place of creation.

He looked into the spectroscope and saw—not the expected spectrum, no! Only a single bright line! At first he suspected some displacement of the prism, and that he was looking at the reflection of the illuminated slit from one of its faces. But according to his own description, and in his own words, the true interpretation flashed upon him after a moment's thought. The light of the nebula was monochromatic, and so, unlike any other light as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated into a single bright line, having a width corresponding to the width of the slit, and occupying in the instrument a position at that part of the spectrum to which its light belongs in refrangibility. A little closer looking showed two other bright lines on the side towards the blue, all the three lines being separated by intervals relatively dark.

He proclaimed:—

"The riddle of the nebulae was solved. The answer which had come to us in the light itself read: Not an aggregation of stars, but a luminous gas. Stars after the order of our Sun, and of the brighter stars, would give a different spectrum; the light of this nebula had clearly been emitted by a luminous gas."

Continued observations led to the conviction of the very great probability of an evolution in mighty space of starry creations going on from an unfathomable past into an equally unfathomable future. This master mind had grasped the birth of the stars; his keenness of intellect, quick to discern, as rapidly to combine, had deduced from the very signals of the stellar universe the genesis of its atomic life. It is when we ponder over such mighty results that we are overwhelmed with the capabilities of the human intellect. HUGGINS gives us his conclusions in the following words:—

"A time surely existed when the matter now condensed into the Sun and planets filled the whole space occupied by the solar system, in the condition of gas, which then appeared as a glowing nebula, after the order, it may be, of some existing in the heavens. There remained no room for doubt that the nebulae, which our telescopes reveal to us, are the early stages of long processions of cosmical events, which correspond broadly to those required by the nebular hypothesis in one or other of its forms."

Another important event in astrophysics was marked by his observations on a new star in *Corona Borealis*, to which his attention had been called by JOHN BIRMINGHAM on May 18, 1866. HUGGINS viewed the spectrum of this star on this evening, after it had already fallen in brightness below the third magnitude, and obtained a result up to that time unprecedented. The spectrum was that of the solar order, with its numberless dark lines, upon which appeared a few very bright lines. There was little doubt in his mind that at least two of these lines belonged to hydrogen. It led him to believe that an unusual brilliancy of these lines was due to a gas of higher temperature than that of the star's photosphere, and that suggested to him a cosmic catastrophe, a sudden and vast convulsion which had taken place in a star that from emitting but faint light had blazed up to one of second magnitude, falling again in brightness within the short period of twelve days to one of the eighth.

Volcanic forces or the disturbing approach or partial collision of another dark star may have been the cause of the sudden outburst. HUGGINS says: "The essential character of the explanation lay in the suggestion of a possible chemical combination of some of the escaping highly heated gases from within, when cooled by the sudden expansion which might give rise to an outburst of flame at once very brilliant and of very short duration."

In these three cases, taken from the early labors of our medalist, we have covered three periods of cosmic life. If the gaseous nebula may represent the cradle or birth of a sun, a world, or a system, the work upon the spectra of the stars led to a new knowledge of their chemical nature and relative physical conditions, and may appeal to us as exhibiting the various activities of existing individual cosmic life; while the last phenomenon referred to in the sudden brightness of an

unknown member of the universe may represent to us its sudden destruction or tragic death.

But within these three stages of cosmic struggle there lay an enormous field of operation for this fertile mind, which was ever on the alert for new signals from the heavenly hosts.

The spectra of comets engaged his attention, and he found frequent opportunities to observe them. The faint comets did not lead to any very definite conclusions, but observations made on a bright wanderer in June, 1868, resulted in showing that the three bright bands, or flutings, of the spectrum agreed in position with three similar flutings in the brightest part of the spectrum of carbon. Very ingenious modes of comparison confirmed his expectation, and referring to the method and its results he states: "The comet, though subtle as Sphinx, had at last yielded up its secret. The principal part of its light was emitted by luminous vapor of carbon."

In 1881 an opportunity was offered for the first time to observe a bright comet by the spectroscope, fortified with suitable photographic plates, and this made it possible to extend the examination of its light into the invisible region of the spectrum at the blue end. The photograph brought to light a new fact; it led to the knowledge that nitrogen, as well as carbon and hydrogen, exists in comets.

Numerous systematic observations and original researches were made in his chosen special field of labor, all fruitful issues and events in the rapidly developing science of astrophysics. Fixed stars, nebulae, comets, and possible new stars were compelled to yield their secrets to him. He devoted some attention to spectroscopic observation of the Sun, and also to the effects of sun-spots in their modification of the spectrum, and devised a method for determining the chemical constitution and the shape of the solar protuberances.

He sought for an explanation of the mysterious solar corona, to which he referred in his Bakerian Lecture for 1885, and in his Presidential Address before the British Association in 1891, and again in a short discussion of an explanation suggested by SCHEINER in 1900, in which he says that the matter of the corona is still open to questions of interest, and must be left for new information that may reasonably be expected from the observation of future eclipses.

The photography of star spectra occupied his time from an early period, for he attempted to obtain such spectra as long ago as 1864; but it was only after the dry-plate process became a reality that he successfully applied this art to the production of spectral images of celestial bodies, which led to many important and interesting discoveries. A book has been published by Sir WILLIAM and Lady HUGGINS (Lady HUGGINS was a former Miss MARGARET MURRAY, of Dublin, whom he married in 1875, and who became his acknowledged principal assistant and collaborator in his researches), in which the progress of photography of stellar spectra is given to the scientific world under the name of "Atlas of Representative Stellar Spectra," a magnificent volume, issued in 1899, with numerous illustrations and artistic chapter initials, by the talented Lady HUGGINS, which may give one an idea of the enormous and painstaking labor bestowed upon this most interesting and far-reaching feature of stellar spectroscopy; it has, indeed, been compared to a dictionary, for with a little stretch of the imagination one may call it "A Handbook of the Language of the Stars."

There remains a special subject in stellar spectroscopy not yet mentioned, but one that is so well known that I need hardly refer to it here, and that is the measurement of the motions of the stars in the line of sight. It is this work which has been taken up at the Lick Observatory, and in which Director CAMPBELL has gained such well-deserved recognition, and through whom this observatory (in the words of Professor NEWCOMB) has gained at once a position of pre-eminence, which it maintains to the present time.

Dr. HUGGINS, as early as 1868, presented to the Royal Society some observations on a small change of refrangibility in a line in the spectrum of *Sirius* as compared with a line of hydrogen. It was known that changes in the position of the lines of the spectrum might be used as an indicator and scale of the radial velocity of the object from which the light emanated, on the principle, suggested by DOPPLER sixty years ago, on which a sound becomes sharper or flatter accordingly as the ear and the sound-producing object approach or recede. This principle applied to the spectrum indicates an approach of the star if the lines are displaced toward the violet end.

and a recession if this shift be toward the red end, providing that the displacement be not caused by pressure. The Earth's motion being known, the final result is the velocity of the star in the line of sight. Referring to his attempts to overcome numerous difficulties that presented themselves in this work, he says:—

“At last, in 1868, I felt able to announce in a paper, printed in the Transactions of the Royal Society for that year, the foundation of this method of research, which, transcending the wildest dreams of an earlier time, enables the astronomer to measure off directly in terrestrial units the invisible motions in the line of sight of the heavenly bodies.”

This method opened up a prolific field for spectroscopists, of whom a number have become very prominent. Improved methods of photography made it possible for Professor VOGEL to determine the motions in the line of sight of over fifty stars, with an accuracy of about an English mile a second. Other votaries, among them our lamented KEELER, have applied the method to a determination of the rotation of the Sun, of *Saturn* and his rings, and of *Jupiter*.

In the “New Astronomy” HUGGINS proposes a method of separating double stars too close to be individually visible. PICKERING and VOGEL have independently discovered by this means an entirely new class of double stars. In the publication above referred to he states that “it would be scarcely possible, without the appearance of great exaggeration, to attempt to sketch out, even in broad outline, the many glorious achievements which doubtless lie before this method of research in the immediate future.”

I think this statement could be applied with equal force to all the different lines of research followed by him, every one of which has opened an avenue of approach to one of the richest mines of scientific labor. The life work of this eminent octogenarian lies open before us, and it is one well done and conscientiously performed. It seems opportune that I should quote from a recent book by Professor SIMON NEWCOMB, one of the most interesting that it has been my privilege to read. I know of nothing that has charmed me more than the perusal of the “Reminiscences of an Astronomer.” And even fearing that in quoting from this book I may repeat in a measure what has already been dwelt upon,

I shall relate to you what our first medalist has to say about the last:—

“For the visiting astronomer scarcely a place in London has more attractions than the modest little observatory and dwelling-house on Upper Tulse Hill, in which Sir WILLIAM HUGGINS has done so much to develop the spectroscopy of the fixed stars. The owner of this charming place was a pioneer in the application of the spectroscope to the analysis of the light of the heavenly bodies, and after nearly forty years of work in this field is still pursuing his researches. The charm of sentiment is added to the cold atmosphere of science by the collaboration of Lady HUGGINS. Almost at the beginning of his work, HUGGINS, analyzing the light of the great nebula of *Orion*, showed that it must proceed from a mass of gas, and not from solid matter, thus making the greatest step possible in our knowledge of these objects. He was also the first to make actual measures of the motions of bright stars to or from our system by observing the wave-length of the rays of light which they absorbed. Quite recently an illustrated account of his observatory and its work has appeared in a splendid folio volume, in which the rigor of science is tempered with a gentle infusion of art which tempts even the non-scientific reader to linger over its pages.”

Sir WILLIAM HUGGINS is now eighty years old, and, as we have seen, has been an active scientist for nearly half a century. Many are the honors that have been heaped upon him. He became President of the Royal Astronomical Society in 1876; President of the British Association in 1891; President of the Royal Society in 1900. He has received a Royal medal, the Rumford medal, and the Copley medal from the Royal Society, and two medals from the Royal Astronomical Society.

Is it not remarkable from what small beginnings this great scientific growth took its origin?—a piece of glass made into the shape of a wedge or prism, refracting the Sun's light, whose rainbow colors might be thrown upon a screen; a beautiful trifling toy that might delight a child.—and that is the spectroscope in its primitive form,—a simple glass, yet with an inherent power to wrest from the mighty universe its most mysterious secrets.

These are the seven colors recited by Sir WILLIAM himself in poetic form:—

“First the flaming red
Sprung vivid forth; the tawny orange next;
And next delicious yellow; by whose side
Fell the kind beams of all-refreshing green.

Then the pure blue, that swells autumnal skies,
 Ethereal played; and then, of sadder hue,
 Emerged the deepened indigo, as when
 The heavy-skirted evening droops with frost;
 While the last gleamings of refracted light
 Died in the fainting violet away."

That these beautiful colors, which God himself placed within the heavens as a symbol of his good will to man, contained more than a poetic meaning, that within them lay a language from the heavens that needed but an inspired interpreter to reveal, has been amply demonstrated by the life's labor of our medalist, Sir WILLIAM HUGGINS.

And in his absence, Mr. Secretary, I shall charge you with the mission of sending the medal to Sir WILLIAM, with our best wishes that he may live to see more years in which to enjoy the fruits of his accomplished work so modestly and unselfishly given to the world.

If our imagination can create the spectrum of a man's life, may his be to the end one crossed by bright lines only.

March 26, 1904.

PHOTOGRAPHS OF BORRELLY'S COMET (1903 c).

BY SEBASTIAN ALBRECHT.

It is aimed in this paper to give a brief account of thirty-six negatives of Comet 1903 c (BORRELLY), obtained at Mount Hamilton between June 22d and August 18th, inclusive.*

Two distinct types of tails persist throughout the entire series of photographs. The principal tail is long and straight in its general direction, and in a large number of cases can be traced to the edge of the plate, a distance of ten degrees. It developed some very interesting forms, changing its aspect completely from day to day. Several more or less permanent features of the main tail deserve special mention. Its length was always considerable, and it was directed almost exactly away from the Sun. The mean deviation of the tail from the

* A more complete account, with tables of measures and descriptions of the negatives, is published in *L. O. Bulletin* No. 52, and in the *Astro-Physical Journal*, March, 1904.



1903. July 23



1903. July 24

COMET 1903 c, [BORRELLY]

radius vector from the comet to the Sun was somewhat less than two degrees. The main tail, in general, widens out after leaving the head, and on a large number of plates divides into two distinct branches. From measures of the directions of the two branches of the main tail on eight plates, the mean angular distance between them was found to be about seven degrees. There is a marked contrast in the appearance of the primary tail on the negatives taken in July and on those taken in August. The tail on the plates of July is, with three exceptions, which will be mentioned later, smooth and continuous, while on the August plates it is twisted and full of condensations, indicating greatly increased activity as the comet approached perihelion.

The other tail is short and very much curved, and presents practically the same appearance on all the negatives. It is bright even on the plates of June. Its length is about one and one half degrees. In the process of intensification necessary to reproduce the principal features of the primary tail, the coma has become so strongly intensified as to almost completely obscure the secondary tail. This is especially true for the plate of July 23d, where barely a trace of the short tail can be seen on the side opposite the new tail which appears on that plate. On the plate of June 22d the short tail made an angle of twenty-six degrees with the primary tail. This angle gradually diminished, owing to the foreshortening produced by the Earth's approach to the plane of the comet's orbit, until about the middle of July, when the two tails appeared to coincide. After the passage of the Earth through the plane of the orbit, the angle again increased until August 18th, when it amounted to thirty-three degrees.

In addition to these two tails, occasional streamers developed, some of which branched off from the main tail, while others issued directly from the head.

Three of the negatives, those of July 23d, 24th, and 26th, deserve special mention, on account of unusual structure in the principal tail. The plate of July 23d shows two long masses entirely separated from the main tail at about three and one half degrees from the nucleus, and on the side following the radius vector. One of these extends to the edge of the plate, a distance of about ten degrees from the head. The main tail

extends to a distance of about five degrees from the head, and a long, narrow streamer leaves it about two degrees from the head. These four branches, together with two prominent bands in the main tail near the head, all making small angles with the general direction of the tail, present a wavelike appearance. The entire main tail somewhat resembles a rope, one end of which is unraveled and which has two of the loose strands severed.

The plate of July 23d shows, in addition, an entirely new tail issuing from the head in advance of the radius vector, preceding it by six degrees, but being bent toward the radius vector shortly after leaving the coma. This tail assumes the forked characteristic which the main tail shows on a majority of the plates. Its angular width is 4.6 degrees, and on the original negative it can easily be traced to a distance of four degrees from the head. The plate of July 24th does not record this extra tail. The plate of the 24th shows a detached section, preceding the radius vector, which is composed of two distinct portions, the shorter being nearer the head and pointing directly toward it. This can best be seen in the accompanying illustration by holding it obliquely, so that the eye is raised only slightly above the plane of the paper. This plate also records a detached streamer on the following side of the main tail, and directly opposite the detached section referred to above. The interval from the 23d to the 24th of July was evidently one of unusual activity. The plate of July 25th shows no unusual forms. The plate of July 26th shows the main tail broken at a distance of about three and one half degrees from the head.

From a comparison of the plate of July 24th with reproductions of two plates taken by BARNARD and WALLACE at the Yerkes Observatory and one by QUENISSET at Nanterre, it was found that, in the interval of seven hours during which these photographs were taken, the detached section of the primary tail was receding from the nucleus at an average rate of thirty-five miles per second, which is equivalent to thirteen miles relative to the Sun.



1903. July 25



1903. August 12

COMET 1903 c, [BORRELLY]

DEDICATION OF THE STUDENTS' OBSERVATORY,
AT BERKELEY.

INTRODUCTORY REMARKS.

BY DIRECTOR W. W. CAMPBELL.

(Before the Society at the meeting in Berkeley, January 30, 1904.)

There is probably no situation in which men and their work are more accurately judged than in a great modern university. The real and the superficial are almost unerringly sorted out by the open-minded and quick-witted students, by colleagues on the faculties, and by the conscientious and responsible heads of the institutions. The departments which seem to prosper year after year are really prosperous and are deservedly so.

One of the conspicuous features of university governments is an application of a very old truth—to the department that hath shall be given.

The addition to the Students' Observatory which we have met to dedicate this evening is an illustration of this fact. It is not to be thought of as an addition to California's list of properties; it is not simply a building containing a collection of astronomical instruments,—that would be a museum. Friends have presented the instruments, and the University has accepted, mounted, and covered them, with the expectation, based upon the record of the Department, that they will be used. They are an opportunity, and at the same time a responsibility. It is intended, I think, that they shall be employed for two main purposes: for giving instruction in the fundamental principles of the science, and for making original investigations, principally by the officers of the Department.

The elements of astronomy are taught more or less efficiently in a great number of American schools and colleges. Some of the teaching is real astronomy, and other portions are called astronomy by courtesy. The varieties differ as widely as the work of a local business college differs from that of a great metropolitan banking institution. Our colleges and universities which are successfully teaching the theory and practice of astronomy can almost be counted upon the fingers

of the two hands. Nearly all of them make specialties of certain lines of astronomical work, depending upon the experience of the men in charge; and in these lines the instruction is of a very high grade. But there is, I think, no other American university in which real astronomy is taught so extensively as in the Berkeley Astronomical Department of the University of California. Taking into account also the astrophysical work and opportunities of the Department of Physics, and the encouragement and facilities extended, by fellowships and otherwise, to especially promising students at the Lick Observatory in all lines of research prosecuted there, the astronomical advantages of the University certainly seem to be unsurpassed. It is a pleasure to note that all the men who have taken advantage of them in the past few years have secured appointments to positions which afford them at least the opportunity to make suitable returns.

There is a strong and increasing demand for well-trained men and women to fill university and observatory positions, and I trust that the Berkeley Astronomical Department will have continually growing success in starting promising students on their careers in this pure science.

It is not desirable that these new instruments should cause individual students to spend more time on their undergraduate astronomy; but, rather, that they should spend the same amount of time more efficiently, and that a greater number of students should be attracted to the study of astronomy and have their requirements suitably met. If these instruments should entice the future astronomer away from simultaneous studies in the English language and literature, in history, in economics, and in other studies which broaden and balance him, then they would in fact be a detriment. Any undergraduate training in our science secured at the sacrifice of a liberal and broad education is a failure. No matter how excellent his special training, the young astronomer starts upon his profession badly handicapped if he is not proficient in speaking and writing his own language, and if he does not possess reasonable knowledge of many subjects apparently unrelated to his science.

In these days of great things one frequently hears the opinion expressed that for useful investigational work in astron-

omy powerful telescopes are demanded. It is true that recent advances in our science have been due in large part to the possession of powerful and expensive equipment. But the directors of observatories possessing such equipment are wisely restricting their programmes of work to those problems which cannot be solved equally well with small instruments; and it would be a grievous mistake to assume that the small telescope in suitable hands is not able to render good account of itself. Reference to the work of a few small telescopes makes interesting reading:—

The observations for ARGELANDER'S *Durchmusterung*, the work consulted more frequently than any other by astronomers, were made with a 3-inch refractor;

The Cordoba *Durchmusterung*, continuing the above work to the South Pole, is based upon observations made with a 5-inch telescope;

Nearly all unexpected comets are discovered with instruments not more than six inches in diameter, and great numbers of accurate determinations of their positions are made with the same telescopes;

Remarkable contributions to our knowledge of the forms and development of comets have been made in the past twelve years almost wholly with photographic telescopes from four to six inches in diameter;

Our comprehension of the elements which contribute to success in the difficult work of measuring the motions of the stars in the line of sight has increased until to-day we should be able to prove with a 6-inch telescope and a suitable spectrograph that *Capella* is a spectroscopic binary star whose two components, of nearly equal size, revolve around their common center of mass in 104 days;

The work of Dr. ROBERTS in the past ten years, in South Africa, on the photometry of variable stars, has been remarkable for its accuracy, quantity, and systematic nature; yet it has all been done with telescopes varying in size from one to three inches;

KEELER'S spectrographic observations of the velocities in the ring system of *Saturn*, in my opinion, constitute the most beautiful individual observation made in recent times; yet his telescope, located in a region notorious for its poor atmos-

pheric conditions for such work, was only thirteen inches in diameter.

In closing this informal address, I beg to relate an incident which bears upon the question of the success of the excellent and beautifully finished new instruments which we are invited to inspect at the close of this meeting: In the year 1893, a prominent citizen of California, connected at the time with the educational system of the State, visited the Lick Observatory and inspected its instruments. I well recall his expression of disapproval when he saw that the brass tube of the Crocker telescope, with which Professor BARNARD was securing his famous photographs of the Milky Way and comets, looked worn, and did not carry the polish which one sees on the companion-rail of a steamship. And later in the day, when the star spectroscope, which Professor KEELER had used so successfully in measuring the motions of the planetary nebulae, and in investigations on objects of special interest, was seen to be worn and scratched from five years' continual use, it was remarked, quite forcibly, that we did not seem to be taking very good care of our instruments.

The most comprehensive good wish that I can make for the Berkeley Astronomical Department, in whose success we all rejoice, is, that when the Astronomical Society of the Pacific is again invited to hold a meeting in the Students' Observatory we shall find the varnish worn away from many parts of these new instruments.

HISTORY AND AIMS OF THE STUDENTS' OBSERVATORY.*

BY A. O. LEUSCHNER.

The buildings and equipment which we dedicate to-night bring us considerably nearer to the realization of the hope of having at the University of California a well-equipped Students' Observatory. Our hearts are full of gratitude to those who have helped us meet our most pressing needs.

* Address delivered before the Astronomical Society of the Pacific, January 30, 1904, at the dedication of the new observatory buildings of the University of California. Rewritten for the *Publications of the Astronomical Society of the Pacific*.

On behalf of the Berkeley Astronomical Department, I thank Mr. WILLIAM M. PIERSON for the gift of his splendid eight-inch reflector; Mrs. HERMAN OELRICHS, for the donation of the late Senator FAIR's five-inch refractor; the President and the Hon. Board of Regents, for the erection of suitable buildings; and last, but not least, again, President WHEELER, who is ever taking a keen interest in all that concerns our students, for causing the regular budget of the Students' Observatory to be increased so as to enable us to make material additions to our equipment. The total value of our new possessions is over nine thousand dollars, the value of the new equipment alone being over five thousand dollars. Our thanks are also due to Professor JOHN GALEN HOWARD, Supervising Architect of the University, and his staff, for the care taken in meeting our requirements, with reference to the design of the new buildings, and to the California School of Mechanical Arts, particularly to Messrs. G. A. MERRILL and E. T. HEWITT, for their aid in the construction of the photographic telescope and the running-gears of the new domes. Dr. A. F. GILLIHAN and Mr. VAL. ARNTZEN are to be particularly complimented for the energy and efficiency displayed by them in the construction of the photographic telescope and in putting our new equipment in place.

The new buildings are intended to be temporary, and are constructed of wood. They consist of a main building, with domes for the Oelrichs and photographic telescopes, and a separate dome for the Pierson reflector. The main building extends north and south on the west slope of the hill on which the Students' Observatory is situated, and faces east. It contains, aside from the domes, two large rooms, 30 x 30 and 20 x 30. on one floor; also a photographic dark-room and store-rooms in the basement. The reflector dome is located on the south slope of the hill.

The new equipment includes the Pierson (Newtonian) reflector, of 8 inches aperture and 6 feet focal length, by BRASHEAR; the Oelrichs refractor, of 5 inches aperture and $6\frac{1}{3}$ feet focal length, lens by ALVAN CLARK and mounting by GAERTNER & Co., Chicago; a mounting designed and constructed in the University for the Harrison portrait-lens, of $5\frac{1}{2}$ inches aperture and 22 inches focal length, a Repsold

measuring-apparatus for measuring positions on photographic plates, and a Gaertner comparator for measuring spectrograms.

In addition to these improvements a wooden platform surrounding three piers has been erected in the open space between the old and new buildings, for use as an open-air observatory with portable instruments. The three instruments in question, which have been loaned to the department, are a 3-inch equatorial of 4 feet focal length, a $1\frac{3}{4}$ -inch Browning transit-instrument, and a $1\frac{1}{8}$ -inch altazimuth instrument, with circles graduated to 5".

Our new acquisitions are primarily intended to increase the efficiency of our instruction in practical astronomy, but they will also afford the members of the department considerable opportunity for original observation.

The Students' Observatory of the University of California occupies a unique position among the astronomical observatories in this and other countries. Founded originally for the purpose of giving a few civil-engineering students the astronomical knowledge necessary to their profession, its development ever since has been in the direction of creating new opportunities for the study of astronomy in all its branches, until now it is well recognized that the University of California, with its two astronomical departments—the Lick and the Berkeley—has a well-organized and prominent training-school for the profession of astronomy. It was through the efforts of Professor FRANK SOULÉ, head of the Department of Civil Engineering, ably assisted by Professor WILLIAM THOMAS WELKER, then Superintendent of Public Instruction, that an appropriation of ten thousand dollars for the erection of a Students' Observatory was secured from the Legislature of the year 1885. The appropriation was most wisely and economically expended, about one half being applied to the erection of the necessary building and one half to equipment.

Instruction in this little observatory commenced in the fall of 1887. I well remember the fine impression which the observatory made upon me when I first visited the same in 1889, during my career as a student in the Lick Observatory. Coming down from the great Lick Observatory, with its huge and magnificent instruments and perfect equipment, the Stu-

dents' Observatory impressed me as a neat and complete model of what a large observatory should be.

The observatory building then consisted of the dome, housing the 6-inch equatorial of $8\frac{1}{3}$ feet focal length; the small instrument-room for minor apparatus; the transit-room, containing the 3-inch Davidson zenith and transit telescope; the Howard mean-time clock, the chronograph, and the switch-board; and two small rooms. A small house in the rear harbored the Ewing, Gray, and Duplex seismographs. The minor equipment included a spectroscope, sextants, chronometers, level-trier, and spherometer.

Since then the observatory has been enlarged four times, by the addition of a computing-room, 17 x 30; an office for the Director; a lecture-room, seating 200 students; and the buildings which are being dedicated to-night.

In the earlier days the headquarters of the Department of Civil Engineering and Astronomy, of which the Students' Observatory formed the other part, consisted of one room on the top floor of North Hall. The head of the department and one instructor made up the staff. It was not long before the burden of carrying the instruction in civil engineering as well as in astronomy became so great that Professor SOULÉ was forced to ask to be relieved of the latter, and in 1892 the courses in general and practical astronomy, offered for the benefit of the civil-engineering students, were assigned to me while I still retained my connection with the Department of Mathematics.

It was at this time that the tremendous possibilities in the University of California for the development of a successful department of instruction first impressed themselves upon me.

The ideals which since then have constantly been kept in mind were first to shape the undergraduate work in astronomy so that upon graduation the student would be found fully qualified to take part as an assistant in the regular work of a large observatory, and then to develop graduate instruction in such lines as could be satisfactorily undertaken at Berkeley. At the same time the original purpose of the observatory—to afford the necessary instruction in astronomy and geodesy to civil-engineering students—has been carefully adhered to. Provision has also been made for special instruction in navi-

gation and nautical astronomy for students in the College of Commerce. Aside from these functions of the observatory, which provide instruction for students with specific views in mind, the department has organized general lecture and observatory courses, open to all students of the University, for the benefit of those who wish to familiarize themselves with the fundamental principles of astronomical science, their philosophy and historical development. In these courses special attention is paid to modern methods of research and new discoveries. Among others, the course in modern astronomy is given jointly by the Lick and the Berkeley Astronomical Departments and every member of the University enjoys, therefore, the opportunity of being brought into immediate contact with the most recent work of our great Observatory at Mount Hamilton.

That there always has been and now is call for a thorough training-school for the astronomical professions needs hardly to be emphasized. Perhaps no science attracts the popular fancy more than astronomy. As a result many gifted men and women acquire small telescopes and devote themselves as amateurs to a certain limited class of observations, often reaching therein a perfection which places their names prominently before the world. A university should extend to them every opportunity to combine with their enthusiasm, energy, and brilliancy a profound knowledge of the necessary principles of mathematics, physics, and astronomy. Many university graduates who in their undergraduate career plan to become astronomers later find that the institutions which they have attended were not prepared to give them the necessary instruction and guidance.

The necessity of a thorough preparation for the professions of medicine, law, and engineering has long been recognized, and the energies of most universities are bent on offering the best possible preparation for them. Of the pure sciences none is so much in need of similar attention as astronomy, as it depends in an unusual degree upon allied sciences, particularly upon mathematics and physics.

The question, however, might arise whether or not the organization of a department of instruction in astronomy at Berkeley would involve a serious and undesirable duplication

of the work of the great Lick Observatory, which forms an integral part of the University. We might ask ourselves whether a university should abandon its medical instruction because it is in touch with famous hospitals. Would the hospital work be of benefit to any one but a qualified student for further experience? Is such a university not all the more under obligation to organize the best possible medical instruction, so as to give its young doctors the full benefit of the available hospital opportunities? Or would it be feasible to attempt the instruction in the various branches of science upon which medicine depends in the hospital itself? And, further, ought graduate or research work in astronomy be attempted at Berkeley? Is not the work of our new Physiological Laboratory under Professor LOEB of the highest importance to medical science? Is there not research work in astronomy which is similarly related to the observational work of a great observatory? Among others, *theoretical astronomy* and *celestial mechanics* certainly are.

The two directions in which the energies of the department at Berkeley ought to be applied, clearly defined themselves at the outset, and ever since the aim of the department has been to develop elementary and advanced instruction in all branches of astronomy, and to organize, in particular, graduate and research work in theoretical astronomy and celestial mechanics.

Thus our aims have been to supplement rather than duplicate the work of our great Observatory at Mount Hamilton. No astronomical department, however, can be of great service to intending astronomers without the hearty co-operation of other departments, particularly of mathematics and physics. It is only fitting that on this occasion acknowledgment should be made of the hearty co-operation which the heads of these departments in this University have shown at all times in providing for the needs of our astronomical students.

The first important step in the development of our so-called "School of Astronomy" was taken in 1894, when the College of Civil Engineering organized a special undergraduate course in astronomy and geodesy. With the organization of our College of Natural Sciences and the growing demand for instruction in pure astronomy, this course was taken out of the College of Civil Engineering. A few years later the Stu-

dents' Observatory was separated from the Department of Civil Engineering and Astronomy, the new department receiving the name of "Berkeley Astronomical Department."

A new impetus was given to the efficiency of the work of higher instruction in astronomy in 1898, when, at the recommendation of Director KEELER, a vacancy in the regular staff of the Lick Observatory was filled by the appointment of three graduates of the University of California to fellowships in the Lick Observatory, with the privilege of spending one term each year in graduate work at Berkeley.

When I made a suggestion in this direction to Professor KEELER on the day of his arrival in California, he expressed his doubts as to the value in a large observatory of young graduates whose sole experience consisted in the astronomical work done as undergraduates, but he agreed to try the experiment for one year. A few months later, at a meeting of the heads of departments at Berkeley, he expressed regret that more fellowships were not available for our graduates. Since then the Lick and the Berkeley astronomical departments have commenced to vie with each other in meeting the needs of graduate students.

While at first the time of Fellows at Mount Hamilton, by force of circumstances, was much taken up with ordinary routine work, Director CAMPBELL is lending his energies more and more to create for them opportunities and facilities for original research, so that it would seem that at present, through the co-operation of the various departments concerned, the organization of the instruction in astronomy and its allied subjects, particularly for candidates for the degree of Doctor of Philosophy, leaves little to be desired.

The University of California has already turned out a formidable array of young astronomers. Some of its graduates are at the head of astronomical departments in Eastern institutions. The two men who compose the staff of the Mills Expedition of the Lick Observatory to South America were first introduced to the science of astronomy in this building. One man is a research assistant in theoretical work under Professor NEWCOMB in the Carnegie Institution at Washington. Several are rapidly rising in the United States Coast and Geodetic Survey. One is instructor in this depart-

ment, and so on. Eight have been found worthy of appointment to fellowships in the Lick Observatory. In this connection, it may be stated that only students who give evidence of exceptional qualifications as accurate observers and computers, and of ability for original research, are recommended by the Berkeley Astronomical Department for admission to the Lick Observatory.

Many students of astronomy turn their eyes to California for the completion of their training. During the few weeks which have elapsed since the opening of the current semester, this department has received no less than four applications from men and women already actively engaged in astronomical work, with reference to the conditions on which they might continue their theoretical work at Berkeley, and no doubt Director CAMPBELL receives even more applications from advanced students who desire to profit by the unexcelled opportunities of the Lick Observatory.

Thus our efforts seem not to have been in vain. Not long ago, Professor NEWCOMB was reported to have stated that there were two things standing out prominently in astronomical science of to-day: on the one hand the never-ceasing flow of new and startling observational results from the Lick Observatory, and on the other the production of men, well trained for their profession, in the University of California.

It is our constant aim to turn out men who are not merely astronomical practitioners, but *scholars* in the true sense of the word. It is scholars who are needed in astronomy—men capable of promoting science.

An outline of the various courses of instruction offered to astronomical students has been printed by the University under the title "Announcement to Students" by the Lick Astronomical Department and the Berkeley Astronomical Department. It may not, however, be without interest to state here a few characteristic features of the instruction given in this department. First of all, we make it clear to students who desire to prepare for an astronomical profession that their chief reward in later life will consist in the satisfaction which they will derive from their work. Only those who prove themselves to be exceptionally well fitted for astronomical work are encouraged to continue their studies. The quality of

the students enrolled, and not numbers, count in our advanced classes. At all times a close personal contact between students and instructors is preserved, the student sharing whatever problem the instructor may be engaged upon.

In the practical courses we have no set programme of observations and reductions. A student is kept at work from the very beginning with the same instrument—generally the sextant—until he can use it with the skill of an experienced astronomer. This means slow progress at first, but our experience has taught us that the student who thoroughly masters one instrument is not satisfied until he can handle every other instrument equally well. It is in this way that the student will gradually acquire that taste for thoroughness and accuracy so characteristic of BESSEL. With the instrument which he has mastered the student takes part in such work as the observatory undertakes from time to time. Students are not taught to do approximate work first, but the greatest accuracy is aimed at from the outset. Approximate work where it is sufficient can only then be done intelligently, when the subject is first thoroughly mastered. Problems are selected which require the greatest skill. Thus by stellar distances students have determined with great accuracy the eccentricities of our sextants and have determined the longitude by lunar distances. In practice the last-named experiment has become obscure, but its training value cannot be underestimated. By the telegraphic method students have furnished the observatory with accurate determinations of the differences in longitude between Berkeley, Mount Hamilton, and San Francisco. Extended latitude series by TALCOTT's method are available for discussion; similarly, comets, asteroids, and variable stars are observed from time to time, etc.

In theoretical work the same thoroughness is aimed at. Independent thought is cultivated in students, as well as a critical attitude toward what they receive in lectures or from books. Mechanical reduction of observations without a thorough knowledge of the subject is distinctly discouraged. In the theory of orbits a comparative study is made of the various methods proposed for deriving the elements of newly discovered comets or asteroids, with a view to enable the student to select in a given case the method best suited to the solution of

the orbit on the basis of the underlying conditions. A senior, before graduation, is expected to be ready to calculate at a moment's notice a preliminary orbit and ephemeris of a newly discovered comet or asteroid.

This work has been extensively practiced in the past, and on more than one occasion students of this University were the first to announce the orbit of a new comet. By making the student participate in the real astronomical work of the day, his ambition and enthusiasm are constantly stirred.

The numerical determination of the perturbations of the Watson asteroids supplements the work in the seminary or the lecture-room.

A great part of the scientific output of the Students' Observatory must be considered to consist in the later achievements of the men who go forth from it. Owing to the large amount of time devoted to the training of students the members of the department are naturally handicapped in prosecuting their own researches. It is not uncommon for us to find ourselves called upon to drop our own investigations at a critical point, in order to assist a student in his work. Nevertheless, we have been able to publish some observations and theoretical investigations which are not without value, and several important papers are now awaiting the finishing touches for publication.

This account of the aims and the history of the Students' Observatory would not be complete without touching upon some of the wants still felt. Aside from the new observatory which is to form part of the Greater University under the PHOEBE HEARST plans, this department needs above all the establishment of some scholarships or fellowships.

I trust that the members of the Astronomical Society of the Pacific, whom we so gladly welcome here to-night, and who I hope will be seen frequently in these buildings hereafter, will aid us in our ambitions. Perhaps some day they may wish to make their headquarters on these grounds, thus benefiting themselves and us by closer contact with one another.

THE CONSTANT OF REFRACTION.

BY RUSSELL TRACY CRAWFORD.

(Read before the meeting of the Society held in Berkeley, January 30, 1904.)

The phenomenon known as refraction was first mentioned by and probably discovered by PTOLEMY, who lived about the second century A. D. In his famous treatise on optics he points out that the light coming to us from a star or heavenly body, on entering our atmosphere and traversing it to its lower and denser portions, is gradually bent or *refracted*, the result being that the object appears to the observer to be nearer the zenith than it actually is. He shows further that this bending ranges from zero at the zenith to a maximum at the horizon.

WALTHER, who worked in the fifteenth century A. D., was the first one to make any successful attempt to allow for atmospheric refraction in reducing observations.

TYCHO, who is celebrated for his wonderful series of accurate observations, recognized fully the importance of refraction, and consequently made a series of observations to find out the amount of displacement of an object, due to this bending for different parts of the sky, and constructed the first table of refraction. Although it was not a very accurate one, it marks an epoch in the study of this phenomenon. KEPLER, following TYCHO, made a considerable improvement in the theory of astronomical refraction.

The law of refraction was discovered by SNELL in the early part of the seventeenth century. In the latter part of this same century, CASSINI computed a new table of refractions which was an improvement upon KEPLER'S. This was, in turn, followed by a further improvement by BRADLEY in the early part of the eighteenth century.

About 1818 BESSEL gave us his theory of refraction, which is the one used to-day. "Although the complete theoretical solution was then, as now, unattainable, he succeeded in constructing a table of refractions which agreed very closely with observations, and was presented in such a form that the necessary correction for a star in almost any position could be obtained with very little trouble."

The importance of refraction in any problem involving, either directly or indirectly, the zenith distance of an object is evident. The amount of the bending depends upon two things, the density of the air surrounding the observer, and the angle at which the ray of light strikes the refracting medium. As for the variation with the angle of incidence, we may say that refraction varies (very nearly) directly as the tangent of the angle of incidence. The density of the air depends principally upon the elevation above sea-level, and the temperature. BESSEL's theory takes account of all these things, and in this theory is involved what is known as the constant of refraction.

We might now ask what we mean by the constant of refraction, or what is the constant of refraction. It is *not* a number representing something of which we can form a definite picture, as we can of the constant of aberration, for instance, which is the angle whose tangent is the ratio of the velocity of the Earth in its orbit to the velocity of light; but it is one of two numbers which enter as constants into the general expression of refraction, and cannot be described in words, but merely represented analytically. These two constants are usually designated α and β ; but the one called α is known as *the* constant of refraction.

The values of these constants may be found from theory by making some assumption as to the law of the decrease of density of the air for increasing heights above the surface of the Earth. Several such assumptions have been made and tables of refraction deduced from them; some of them give values of the refraction which agree fairly well with observations for a short distance from the zenith, but fail utterly for large zenith distances. The hypothesis presented by BESSEL, however, holds very well indeed for all zenith distances down to about 85° . It is upon this hypothesis that modern refraction tables are based.

First, then, tables were made from these theoretical values of the constants, and corrections have since been made to them by making use of the discrepancies found to exist between the theoretical values of the refractions and the actually observed values. These discrepancies are small; so small, in fact, that we may regard the formula for refraction, which in-

volves these constants, as representing the *law of refraction* well enough, but they are too large to give very fine results, such as are needed in work with the meridian-circle. The constants of refraction, therefore, must receive small corrections in order to make theory and observation harmonize. The constant β is small, and is undoubtedly very accurately known, so that our attention, for the present, will be directed wholly to the constant of refraction, a .

Considering, then, that no correction to β is needed, the following equation can be shown to exist:—

$$dr = \frac{r}{a} da$$

in which r is the refraction, a the constant, dr the difference between the observed and the computed refraction, and da the small correction to be applied to the constant, upon which the computed refraction depends, to obtain the constant which will agree with the observations.

The whole problem, therefore, resolves itself into finding some means of deriving the true refractions from observations so that we may form the quantity dr . There are several methods of obtaining refractions from observations. The one generally used, and which gives excellent results, is by observations of circumpolar stars. I shall explain this method in the words of YOUNG, taken from his *General Astronomy*:—

“At an observatory whose latitude exceeds 45° select some star which passes through the zenith at upper culmination. It will not be affected by refraction at the zenith, while at the lower culmination, twelve hours later, it will. With the meridian-circle observe its polar distance in both positions, determining the ‘polar point’ of the circle in the usual way. If the polar point were not itself affected by refraction, the simple difference between the two results for the star’s polar distance, obtained from the upper and lower observations, would be the refraction for the lower point.

“As a *first approximation*, however, we may neglect the refraction at the pole, and thus obtain a *first approximate* lower refraction. By means of this we may compute an *approximate* polar refraction, and so get a first ‘corrected polar point.’ With this compute a second approximate lower refraction, which will be much more nearly right than the first; this will give a second ‘corrected polar point’; this will in turn give us a third approximation to the refraction; and so on. But it would never be necessary to go beyond the third, as the approximation is very rapid. If the star does not go exactly through the zenith, it is only necessary to compute each time approximate refractions for its upper observation, as well as for the polar point.”

This method, as I have said, gives excellent results, but it has several disadvantages, which it might be well to note. In the first place, it is easily seen that the computations required are quite complicated because of the approximations which have to be made; further, the latitude and its variation are involved; again, the field of observation is limited; and finally, there must be a wait of twelve hours or six months between the observations at upper and lower culminations. If this wait is twelve hours, one observation, in general, will be made in the daytime under entirely different atmospheric conditions from the one made at night; if the wait is six months, so that both observations may be made at night, the atmospheric conditions will again probably be entirely different at the times of the two observations.

It is my purpose now to present briefly another method by which refractions may be observed. It may be stated as being a "quasi" converse to TALCOTT'S method of determining latitude. Instead of eliminating refractions to get the latitude the method is to determine the refractions by eliminating the latitude, as follows:—

Let z_s = the zenith distance of a southern star.

z_n = the zenith distance of a northern star.

z'_s = the apparent zenith distance of the southern star.

z'_n = the apparent zenith distance of the northern star.

δ_s = the declination of the southern star.

δ_n = the declination of the northern star.

r_s = the refraction of the southern star.

r_n = the refraction of the northern star.

ϕ = the latitude of the meridian-circle.

$$\text{Then } \delta_n = \phi + z_n = \phi + (z'_n + r_n) \quad (1)$$

$$\delta_s = \phi - z_s = \phi - (z'_s + r_s) \quad (2)$$

$$\delta_n - \delta_s = z'_s + z'_n + r_s + r_n \quad (3)$$

$$\text{Let } A = \delta_n - \delta_s \quad (4)$$

$$B = z'_s + z'_n \quad (5)$$

$$\text{Then } A = B + r_s + r_n \quad (6)$$

$$\text{or } r_s + r_n = A - B \quad (7)$$

If now the southern and northern zenith distances were the same, and if, at the times of observing them, the condi-

tions of the atmosphere were the same, the two refractions would be the same,—i. e.—

$$r_s = r_n$$

In this case we have

$$2r = A - B \quad (I)$$

In practice these ideal conditions are only approximately satisfied. We therefore proceed as follows:—

From (7) we have

$$2r_s - r_s + r_n = A - B \quad (8)$$

whence

$$2r_s = (A - B) + (r_s - r_n)$$

and

$$r_s = \frac{1}{2}(A - B) + \frac{1}{2}(r_s - r_n) \quad (II)$$

also

$$r_n = \frac{1}{2}(A - B) + \frac{1}{2}(r_n - r_s)$$

In case the northern star is at lower culmination we shall have:

$$\delta_n = 180^\circ - z_n - \phi \quad (9)$$

$$\delta_s = \phi - z_s \quad (10)$$

$$\delta_n + \delta_s = 180^\circ - z_n - z_s \quad (11)$$

$$= 180^\circ - [z'_n + r_n + z'_s + r_s] \quad (12)$$

$$\text{Hence } r_n + r_s = 180^\circ - [z'_n + z'_s] - [\delta_n + \delta_s] \quad (13)$$

$$\text{and } 2r_s = 180^\circ - [z'_n + z'_s] - [\delta_n + \delta_s] + [r_s - r_n] \quad (14)$$

$$\text{Calling } A' = \delta_n + \delta_s \quad (15)$$

$$\text{and since } B = z'_s + z'_n \quad (5)$$

we have

$$r_s = 90^\circ - \frac{1}{2}[A' + B] + \frac{1}{2}[r_s - r_n] \quad (III)$$

and

$$r_n = 90^\circ - \frac{1}{2}[A' + B] + \frac{1}{2}[r_n - r_s]$$

In order to obtain the refractions from (II) and (III) it is necessary to know the declinations of the stars, their apparent zenith distances (or, rather, the sums of the zenith distances of the pairs of north and south stars), and the differences between the refractions of the pairs.

Observations were made at the Lick Observatory by myself, in accordance with this method during a few months of 1899. The stars used were all fundamental, and in a first approximation their declinations are to be considered absolute. They were taken from Professor NEWCOMB'S "Catalogue of

Fundamental Stars for 1875 and 1900, Reduced to an Absolute System." The apparent zenith distances, or the sums of the zenith distances of the several pairs, are obtained from the meridian-circle observations; and the differences in the refractions are found by computing the refractions from some standard table. In this work the Pulkowa tables have been used. The term $\frac{1}{2} (r_s - r_n)$ being of the nature of a differential refraction, any error in the constant of refraction of the table used will have practically no effect upon this difference. The more nearly ideal conditions (i. e. when $r_s = r_n$) are approached, of course, the better the determination of the refractions will be.

This method has both its advantages and its disadvantages. Among the former, the most important are: First, the total elimination of the latitude, and hence also of its variation; second, the elimination of the nadir, since $(z'_s + z'_n)$ is nothing more nor less than the difference between the circle-readings, and is therefore independent of the zenith point; third, there is no wait of twelve hours or of six months in order to observe a star at both culminations, as is usually done; and fourth, the simplicity of the reductions.

The greatest disadvantage in this method lies in the fact that the declinations of the stars have to be considered known. But by taking fundamental stars, such as those whose places are given by Professor NEWCOMB's new Fundamental Catalogue, and by taking a large number of these stars, this difficulty will be nearly completely eliminated.

The value of the constant found from these observations, reduced by the method just given, is somewhat smaller than that used in the Pulkowa refraction tables. It is $60''.159$ for a pressure of 760^{mm} at 0° and 0° (C.) temperature.

For the sake of comparison, the most important determinations of the constant of refraction are given below. These values are for the conditions $B = 760^{\text{mm}}$ at 0° C. and external thermometer $= 0^\circ$ C. (These values are taken from Professor BAUSCHINGER's "Untersuchungen über die Astronomische Refraction u. s. w.").

1. Fund. Astr.	$60''.320$
2. Tab. Reg.	$.440$
3. Tab. Pulk.	$.268$

4. Fuss. ....	.122
5. Greenw. 1857-1865 . . . . .	.120
6. Pulk. 1865 . . . . .	.209
7. Greenw. 1877-1886 . . . . .	.192
8. Pulk. 1885 . . . . .	.058
9. München . . . . .	.104

The first and second of these are determinations by BESSEL; the third by GYLDÉN; the fifth, by STONE; the sixth, by NYRÉN; the seventh, by NEWCOMB; the eighth, by NYRÉN; and the last, by BAUSCHINGER.

BAUSCHINGER gives weight zero to each of BESSEL's determinations; to the first because there was considerable uncertainty in BRADLEY's meteorological instruments; to the second, because of the uncertainty in reading the meridian-circle (read by vernier to one second). He gives equal weight to the last seven, and gets for a mean

$$\alpha = 60''.153$$

The *apparently* fine agreement of my value with this mean, however, is purely accidental, as can be seen from some further reductions of the observations which were made later. It was noticed that the value of $d\alpha$ derived from individual pairs of stars was a function of the zenith distance of the pair used. Upon plotting these values, using the zenith distance z for abscissa, and $d \log \alpha$ for ordinate, it was easily seen that these values varied quite uniformly with the zenith distance. Therefore, a term depending upon the zenith distance was introduced and the resulting equations solved by the method of least squares. This solution led to the conclusion that the so-called constant of refraction used in the Pulkowa tables needs not only a correction, but a correction for every zenith distance. In other words, the formula from which refractions are computed needs to be modified. Or the formula may be retained unaltered, and the desired agreement between observation and computation may be obtained by correcting the tables used (Pulkowa) not by a constant amount but by a variable one represented in magnitude by the expression

$$\Delta \log \alpha = 0.000101 [56^\circ 38'.8 - z]$$

where z is the zenith distance.

THE WATSON ASTEROIDS.

BY BURT L. NEWKIRK.

(Read at the meeting of the Society held in Berkeley January 30, 1904.)

JAMES C. WATSON was born in the province of Ontario, Canada, January 28, 1838. He graduated at the University of Michigan in 1857, and became Professor of Astronomy and Director of the Observatory of that institution six years later. He was one of our most prominent astronomers, having written a book on theoretical astronomy which is still very widely used in the United States. He died in 1880, at the age of forty-two years. During the course of his scientific career he discovered twenty-two asteroids, and at his death left a sum of money as an endowment fund, the income from which should be used to pay for certain investigations and computations which it is necessary to make in order that these asteroids may not be lost to the scientific world.

Beside the well-known greater planets the Sun's system contains a host of very minute planets called asteroids. They revolve about the Sun in the space between the orbits of *Mars* and *Jupiter*. The first one of these to be discovered was found upon the first night of the nineteenth century, the night of January 1, 1801. This is the asteroid *Ceres*, and it is the brightest, and presumably the largest, of the group, having a diameter of 600 miles. Since the introduction of photographic methods in the search for these bodies, their discovery has been made comparatively easy, and something over five hundred of them have already been found, every year adding twenty or thirty to the list. At the time of WATSON's death, in 1880, less than two hundred had been found. The smallest of these bodies are probably nothing more than great rocks, ten or fifteen miles in diameter. Smaller asteroids than these undoubtedly exist, but are so excessively faint as to elude discovery.

Of all the planets of the Sun's system these asteroids offer the greatest difficulties in the matter of the investigation of their orbits. We say, roughly speaking, that the planets move about the Sun in elliptical orbits; but, more accurately speaking, none of the bodies composing the Sun's system move in

ellipses. According to NEWTON'S law of gravitation, every particle of matter attracts every other particle. If the Sun were attended by one planet only, this planet would move in an ellipse, but since each planet is attracted not only by the Sun, but also by all the other planets, its path is a curve of corresponding complexity. Since the Sun's attraction is generally by far the most powerful of all the forces acting upon any one planet, it is convenient to think of the actual orbit described by a planet as a "disturbed ellipse," as we express it. We picture to ourselves an ellipse which nearly coincides with the actual orbit, and in which the planet would move if the attractive forces of the other planets should at some particular instant cease to operate. The departure of the true orbit from this assumed ellipse, due to the disturbing action of the other planets is called the perturbation of the planet under consideration. The only reason for taking an ellipse as a starting-point in the discussion is one of convenience. A circle, which is a simpler curve from a mathematical point of view, might answer the purpose in some cases better than an ellipse, and for other purposes it is advantageous to take as a starting-point a curve of greater complexity. I refer to the "periplegmatic" curves used by GYLDÉN, which represent the path of the planet throughout a long period of years much better than any ellipse could, but seem to possess no advantages in tracing the planet's motion for a short period of time. It is a comparatively simple matter to compute an elliptic orbit, but to investigate the deviations from this orbit—i. e. the perturbations of a planet—is a task requiring in some cases a tremendous amount of labor and study.

The mathematical difficulties of the problem are such that no general method can be employed for computing the orbits of all the planets. Each planet must be treated with reference to the special difficulties which it presents, and this necessitates an intelligent and discriminating study of the various methods used in investigations of this nature, their advantages and their limitations.

The method employed in any particular case must not only be mathematically correct, but it must also be capable of yielding the desired results with the required degree of accuracy and with a minimum of numerical computation. The method

of most general application is one developed by HANSEN, and modified by HILL, NEWCOMB, and others. Newer methods which possess special advantages in certain cases have been developed by GYLDÉN, BOHLIN, and BRENDÉL. These latter methods are, however, comparatively untried, and it has been found necessary here in the asteroid work at Berkeley to revise BOHLIN's method to some extent, before employing the formulæ given. Upon opening correspondence with BOHLIN, whose method has been used on some asteroids here, Professor LEUSCHNER found that BOHLIN himself had arrived at the same conclusion and was at work upon a revision of his theory.

In the case of the asteroids the problem presents special difficulties because of the proximity of *Jupiter*, which is the largest planet, and exerts a very powerful disturbing force. In most cases, in fact, unless a high degree of accuracy is required, the effect of all the other planets combined is a negligible quantity as compared with the perturbations produced by *Jupiter*. Difficult as the problem is, it is however absolutely necessary to compute the perturbations if we would keep the asteroids from retiring again into the oblivion from which their discoverers drew them. It is not possible to predict the motion of an asteroid ten or fifteen years in advance with sufficient accuracy to permit of its being found again at the end of that time without serious difficulty unless this work is done.

In the light of these remarks, Professor WATSON's object in endowing the twenty-two asteroids discovered by himself will be clear. If their perturbations are not derived, his asteroids will be lost to the world in a few years, but, thanks to the fund he has bequeathed for this purpose, it will be possible to predict their motion for fifty or seventy-five years in advance with sufficient accuracy to enable astronomers of the future to find them again when they are wanted without serious difficulty. One of the twenty-two must be excepted from this statement. The asteroid *Aethra*, whose original path passed close to that of *Mars*, has suffered such violent perturbation that the form of its orbit has been greatly changed, and it has not been identified since, in spite of the diligent search which has been made for it. The tracing of the motion of this planet by means of a special mathematical discussion, which will be an exceedingly difficult matter, is to be undertaken by

Miss HOBE, who is now engaged with me upon the perturbations of the other asteroids, under the direction of Professor LEUSCHNER.

Since Professor WATSON's death, in 1880, the trustees have been trying to carry out the desire expressed in his will, by preparing tables by means of which the motion of these asteroids can be predicted for, say, fifty years in advance, with sufficient accuracy to permit of their being readily found. Up to two years and a half ago, when the work was undertaken by this department, considerable had been done, but little was ready for publication. Since that time the perturbations of ten planets have been computed here in Berkeley, and those of two more are nearing completion. Five others are to be treated by BOHLIN's method, the work on these being already under way: the four remaining asteroids have been made the subject of investigation by other astronomers in Europe and America.

Perhaps the most important result of the investigations of the orbits of the Watson asteroids is the light thrown upon the whole subject of asteroid orbits and the methods best adapted to the various cases that arise. The treatment of twenty-two asteroids yields data which will be very valuable in the solution of one of the great problems which now confronts mathematical astronomy,—namely, that of providing tables by means of which the position of any one of the known asteroids may be found without excessive labor.

Before our tables for finding the planets in future years can be finished it will be necessary to compare the results of our investigations with observations. It is possible by this means greatly to improve the results of the numerical work. For this purpose the photographic telescope and Repsold measuring apparatus will be available. With the help of these instruments we shall be able to observe the positions of the asteroids, and a comparison of observations with theory will lead to a final improvement of the tables before publishing them.

The Watson trustees have, as may be imagined from the long time that has elapsed since Professor WATSON's death without the completion of the task, had great difficulty in getting the work done satisfactorily. They have, however, been very well pleased with the progress made here by Drs. CRAW-

FORD and ROSS, under the supervision of Professor LEUSCHNER, and have now turned the whole work over to the latter to be completed and prepared for publication. The work is being carried on under the auspices of the National Academy of Sciences, and the present Watson trustees are: Professor SIMON NEWCOMB (chairman), Professor LEWIS BOSS, and Professor W. L. ELKIN. It is their intention to have all the results published in due time. It has, however, seemed fitting upon this occasion to offer to those interested in the Berkeley Astronomical Department this brief statement of our connection with the undertaking.

THE PHOTOGRAPHIC EQUATORIAL OF THE STUDENTS'
OBSERVATORY.

BY ALLEN F. GILLIHAN.

(Read before the meeting of the Society, held in Berkeley, January 30, 1904.)

It has been demonstrated by Professors BARNARD, WOLF, and others, that lenses of the portrait type, and of large aperture, on account of their great light-grasping power, are very suitable for obtaining, with long exposures, photographs of very faint stars. Such a lens has been in the possession of the Students' Observatory for some years, but for lack of a suitable mounting, little work could be done with it. From time to time, however, it has been strapped to the tube of the 6-inch equatorial, together with its wooden camera, but as, until recently, the driving clock of this instrument did not perform well, and as there was no slow motion in hour-angle, this mounting was entirely unsuitable for photographic purposes. The need for a suitable mounting was thus greatly felt, particularly so in connection with the department's work on the Watson asteroids, it being the intention to verify by photographic observations their computed positions before tables for these asteroids are constructed.

Correspondence with various instrument-makers developed the fact that a mounting such as was desired could be constructed only at a greater loss of time and cost than seemed desirable. The department, therefore, decided to attempt the construction of a suitable equatorial mounting here in Ber-

keley, and after some study of various mountings the regular Fraunhofer model was selected.

In designing the instrument the special purpose for which it was to be used was kept constantly in mind, the object being to construct an instrument of the utmost efficiency for photographing with short-focus lenses, with a powerful and accurate driving-clock, efficient slow motion in hour-angle to control the clock, with all necessary adjustments to facilitate guiding in the dark, and with simplicity and solidity of mounting. It was also necessary to keep the cost at a minimum.

The design of our 6-inch equatorial being both simple and substantial, was used as a model, objectionable features being eliminated and necessary improvements added. One of the special features of the photographic equatorial is, that the frame has been made very compact and heavy, and in as few parts as possible. The clock has been put in a case with glass doors, situated between the equatorial head and the cast-iron column, where it will be protected from dust and moisture. The case needs to be opened only to regulate the pendulum or to oil the clock, but not to wind it. The starting and stopping mechanism is controlled from the outside of the case by means of a button on the north side of the pier. Considerable expense was saved by using commercial gear-wheels in the clock. The teeth of these wheels appear to be very evenly spaced, but the central hole in each wheel had to be recut, as every one was eccentric.

The governor is YOUNG's double pendulum, which is much used in modern instruments on account of its sensitiveness, even action, and freedom from variations due to changes in temperature or to moisture. An important feature in the clock is, that it requires about forty-five to fifty pounds' weight on the drum to make the governor revolve at the proper speed when it is not connected with the instrument; while with the governor removed and the clock connected with the instrument, it requires only about five or six pounds to drive the instrument; that is, the ratio of the weight required to drive the governor to the weight required to drive the instrument is about as seven or eight to one. When, therefore, an extra camera or other weight is added to the instrument, it will make very little, if any, difference in the speed of the governor. The

clock is provided with maintaining power, and under the present arrangement will run for over three hours with one winding.

Another important part is the worm and worm-wheel, which were cut in the Mechanical Department of the University, the worm-wheel having 480 teeth, and the worm revolving once in three minutes. Mr. G. W. RITCHIE, in the *Astrophysical Journal* for November, 1901, in describing the photographic reflector constructed at the Yerkes Observatory, stated that after the instrument was assembled the worm and worm-wheel were ground together with emery flour and oil for a period of 200 hours, and afterwards polished. To this he ascribes the smooth running of the instrument. In our instrument the worm was connected by pulleys and belting directly with the driving-shaft in the workshop in such a way that when the shaft was revolving the worm-wheel, which under the influence of the driving-clock would revolve once in twenty-four hours, was made to revolve in forty-five seconds. The wheel and worm were ground together, using emery flour and oil, for nearly thirty-three hours, making over 2,600 revolutions of the worm-wheel, which at ordinary speed would be equal to about seven years' continuous running. The oil and emery were then removed, and the wheel and worm were polished, running at the same speed, using oil and rouge, for over four hours, which is equivalent to 340 turns, or nearly one year, of continuous running. In this way any irregularities were ground out, and the worm was firmly seated in the worm-wheel, where it is held in close contact by means of a strong adjustable steel spring.

The slow motion in hour-angle is introduced between the driving-clock and the worm. It is a differential gear or mouse control worked by an endless cord in the hand of the observer. Tangent-screw hour-angle slow motion brought to the eye-end of the instrument by gears is expensive, and besides has limited range; the observer is very liable to jar the instrument in moving the handle. None of these disadvantages prevail with the mouse control; while guiding the observer need not touch the instrument, except in case of a comet moving rapidly in declination. In this event, however, very accurate driving is not essential.

Clamp in hour-angle, clamp and slow motion in declination, are brought to the eye-end as in other instruments. Both slow motions are made particularly delicate, for use with a high-power eye-piece. Four feet six inches of the hour-angle slow-motion cord moves the instrument through one minute of time, and one turn of the declination slow-motion handle corresponds to four minutes in declination.

The declination-sleeve has been made unusually long, and with the circle partly counterbalances the telescope and cameras. The circles have white figures on black background, being easier to read in the dark than black figures on a white ground. The declination-circle is graduated to 30' and reads by verniers to 2'. The hour-circle is graduated to 4^m and reads by verniers to 20^s. These graduations are fine enough for setting purposes.

A flat iron bed-plate 1 ft. x 2 ft. takes the place of the usual saddle on the end of the declination-axis to which the telescope is fastened. On it a wooden platform 2 ft. x 3 ft. is firmly fastened. The guiding telescope, a 3½-inch Mogeys refractor, is fastened to one side of the under surface of this wooden platform, and a balance weight is fastened to the other side. This leaves the upper surface free for screwing on one or more cameras. This platform is a temporary expedient for the purpose of testing various cameras; later the cameras will be fastened directly to the bed-plate.

The polar-axis bearings are conical, and the weight is taken off the upper bearing by a pair of counter friction-wheels suspended in a frame-work which is pulled up by a strong adjustable steel spring. The end-thrust of the polar axis is taken up by an adjustable ball-bearing at the lower end. All those parts of the instrument that may wear or work loose are adjustable, so that lost motion may always be prevented. For example, in the declination slow motion provision is made for taking up lost motion in three directions, so that this very important adjustment can never wear loose.

A few words regarding the photographic lens: it is a C. C. Harrison portrait combination of about 5½ inches aperture and about 22 inches equivalent focus. The camera carries a 6½ x 8½ plate, but the field of view, where the star disks are quite sharp, is limited to about 10 centimeters square,

or about 10° square. An exposure of about twenty minutes on a good night will give impressions of stars of about 11th or 12th magnitude and good measurable images of 10th magnitude stars. As an example of the work possible with this lens, on December 29, 1902, with the camera strapped on the 6-inch equatorial, an exposure was made for $1^h 13^m$ of the region around asteroid (385) 10.1 magnitude, and a distinct trail was found very near the computed position of the asteroid.

A description of the photographic equatorial would not be complete without mentioning those connected with its construction. The heavy castings and their patterns were made by the California School of Mechanical Arts; the heavy machine work is by the J. A. Gray Machine Co.; the composition castings are by the Eureka Foundry; and the circles were graduated by the A. Lietz Co.; all of San Francisco. All other parts of the instrument were constructed by Mr. VALDEMAR ARNTZEN, of the Department of Civil Engineering. He has done all of the finer instrumental work, and also helped in solving several knotty problems in the designing.

No work has been done as yet with this instrument; but it is hoped that it will be possible in the near future to present to the Society a satisfactory report of its work.

A FEW DETAILS OF THE TWELVE-YEAR SUN-SPOT CYCLE.

BY ROSE O'HALLORAN.

Though regularity in the increase and decline of solar activity first led to a recognition of sun-spot periods, still each cycle of change has its individual traits, tendencies, and occasional discrepancies. The cause of periodicity being entirely unknown, such details are of interest, as they may be more than unimportant casualties. The following brief summary of observations from November 1, 1891, to November 1, 1903, contains some of the characteristics of the prolonged cycle that occurred between these dates. According to Professor WOLFER's revision of sun-spot data, a marked minimum took place early in 1890. This extreme stage of unspottedness did

not recur until the summer of 1902; while the last maximum, which showed its approach towards the end of 1891, had its corresponding stage only in October of 1903, so that, dating the cycle either from the extremes of minima or from incoming maxima, its duration was beyond the average period of eleven and one tenth years.

As I used a Brashear refractor four inches in aperture, only very small faint spots were undiscernible in clear weather. When visiting the line of totality of the eclipse of 1900 an interruption of some length occurred, but it makes little change in the outline of decreased spottedness, as the minimum was far advanced. One aim of these observations has been to note the number of times that the photospheric whiteness of the disk has been noticeably invaded. A discolored area, whether stained by one spot or by many, is classed as one disturbance when the sprinkling does not extend beyond twenty-five degrees of the Sun's surface, which, being about the limit of the largest spots, gives some clew as to the probable range of a single eruption. This method, though giving a far less numerical result than if each fragment of a discoloration were counted, avoids including any spot more than once.

From November 1, 1891, to the same date of 1903, the Sun was observed and the results recorded on 2,982 days, and, according to the method adopted, 811 spotted areas were seen on the disk during that time. Two thirds of the disturbances occurred within the first five years, the remainder being distributed over the ensuing years with decreasing frequency until September, 1902, when a slight but distinct increase of activity set in. Of the entire number, about forty sufficiently conspicuous to be visible under favorable conditions without magnifying power may be classed as large; and formations which, from depth of hue combined with enormous extent, were distinctly visible to the world at large crossed the disk on four notable occasions. The first, one of the greatest on record, 150,000 miles in length and 75,000 in breadth, was fully inside the southeast limb on the 4th of February, 1892, and with many changes and divisions continued in view until the 17th. The second, when central in the southern hemisphere, on the 6th and 7th of August, 1893, was nearly 100,000 miles in length, and with much stability of color and form

crossed the disk among a dozen smaller eruptions sprinkled over the spot zones. The third, with compact umbra and enormous penumbra, tinged the southerly tracts from the 2d to the 15th of September, 1898. In one respect it was the most remarkable spot of the cycle. The maximum climax was five years past, the minimum was approaching, when some irresistible counter force shattered the law of quietude over an area 140,000 miles in length. The same hemisphere was also the background of the interesting group of last October. With diversified phases, it lingered from the 5th to the 17th of the month, and, though unequal to the first and third in extent, it far surpassed any sun-storm within the previous five years.



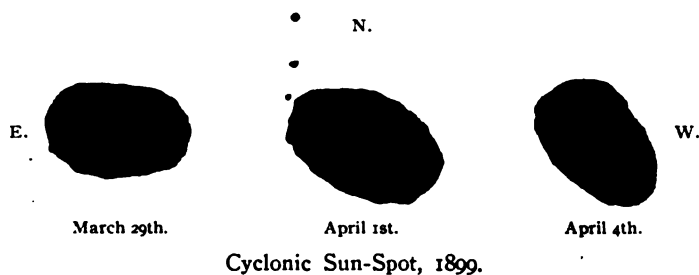
Great Sun-Spot, August 7, 1893.

There is good evidence that many of the large spots were of long duration, and came to view by rotation more than once, but change of form and of position renders complete identification impossible. As in the previous cycle, from 1879 to 1890, the northern zones were more quiescent on the whole than the southern, but the distribution was less unequal, being in the proportion of about seven to ten. This estimate was deduced from 567 disturbances distinctly beyond equatorial zones, as without accurate instruments for the measurement of heliographic latitude perspective effects are misleading at certain seasons.

During the years of maximum, spots frequently appeared in latitudes far from the equator, but from 1897 to 1901 more central zones were chiefly the scene of the diminishing activity, while later a scattering of forces was resumed, which is often a symptom of returning maxima.

In May, 1894, three fourths of the solar circumference was strewn with spots of average size from about twenty to thirty degrees apart; and lesser displays of streaminess were also noticeable three times in 1895, once in 1896, and again in 1898.

As M. FAYE, the French scientist, considers sun-spots to be vortical formations, a whirling tendency is a detail of interest, especially when contrary to the hands of a watch in the southern hemisphere of the Sun, and the reverse in the northern.



Such cyclonic motions were detected in January, 1892, in April, 1899, and also less conspicuously on several other occasions.

On August 25, 1894, the disk was freer from discolorations than on any day when observed during the previous two years and ten months, which included 630 observations. From this time forward an unblemished photosphere was more frequently seen, and days, weeks, and finally months of undisturbed whiteness announced that maximum had gradually given place to minimum. Eighty-six days of unspottedness were distributed throughout 1901, and 147 days throughout 1902. In the latter year, from June 6th to September 11th, when an unspotted disk was viewed on 91 days, the extreme stage of minimum seems to have occurred. After a week of cloudy weather two spots appeared on the 19th of September, and thenceforth a slight increase of spottedness was evident until October, 1903, when the present maximum commenced.

Shadings in the granulated solar surface, often noticeable with a high power on clear days, have been ignored in this summary of observations.

SAN FRANCISCO, CAL.

THE SUPPORTING AND COUNTERWEIGHTING OF
THE PRINCIPAL AXES OF LARGE
TELESCOPES.*

BY C. D. PERRINE.

In a telescope whose moving parts weigh several tons it is desirable to reduce the friction in the bearings as much as possible. This is particularly true in the case of the polar axis, which must be driven by a clock at a very regular rate.

The practice has been to have the axis revolve in fixed boxes, usually lined with Babbitt metal, and to relieve the greater part of the pressure by a system of friction-wheels which are pressed upward against the axis, near the bearing; by suitable weights and levers. This is in effect transferring the pressure to smaller surfaces having slower motions. In some cases a ring of rolls has been used in connection with levers and weights. These systems have reduced the friction materially.

In designing the driving-clock of the new mounting for the Crossley reflector of the Lick Observatory I used a simple form of roller-bearing for the drum-shaft and the next two shafts in the train. This form of bearing was not adopted until after an experimental trial, which resulted most satisfactorily. The admirable performance of these bearings has suggested the suitability of this principle for the axes of large telescopes, particularly the polar axes.† Such bearings would do away with the necessity of any auxiliary system of counterweights, and I have reason to believe that, with proper construction, the friction would be less than with the best of the counterweighted systems. As to their accuracy and freedom from play, there should be no difficulty, judging from those already tried. These fit closely, there is no looseness whatever, and the shaft turns with perfect ease and smoothness.

The construction is simple. There is no frame to hold the rolls in fixed relative positions. The rolls are placed in the

* Read before Section A of the American Association for the Advancement of Science at the St. Louis meeting, December 28, 1903.

† It was not possible to adopt this system in the new telescope-mounting, as the heavy parts had already been constructed.

bearing and are kept from falling out by plates fastened to the body of the bearing. The rolls should fit snugly, but not so closely as to introduce appreciable friction between the elements of their surfaces which are in contact. The ends of the rolls should be beveled slightly, away from the center, leaving only a small surface or knob to come into contact with the plate. The rolls should be of steel, hardened and ground accurately round and to uniform diameters. The shaft should of course be of steel, accurately turned and ground. The bearing should be lined with a shell of steel to form the other rolling surface, although close-grained cast-iron makes a very good surface.

The dimensions of the shaft and rolls should be such that there will be not less than fifteen of the latter, thus always having several rolls which are taking the weight. There will then be less tendency for the rolls to jam or the shaft to settle between two of them. The latter condition would be fatal to the working of the system. If the rolls were long, it is probable that they would work more smoothly if cut into sections.

There is perhaps no more satisfactory way of taking the thrust of a large polar axis than that in common use—a balanced plate and one or two rings of balls.

When the parts which move in declination weigh not over four or five tons, the declination-axis performs very well with Babbitted bearings, the thrust being taken by steel shoulders and collars working against Babbitt. Such axes would, however, move much more easily with rolls, and balls to take the thrust. In large instruments a reduction of the friction of this axis is necessary.

The system of roller-bearings here suggested would be fully as efficient in the case of a large overhang of the polar axis as in the ordinary form of mounting.

If the polar axis is supported on two separate piers, the bearings are entirely independent of each other, and some means of aligning the bearings must be provided. It has usually been the custom in such cases to make the bearing in two parts: a lower section with a broad base, and the usual cap. By providing the lower half with screws for leveling and for lateral adjustment the necessary alignment can be secured. It is, however, an advantage to have the bearings self-aligning. This can be accomplished by making the lower

half of the bearings in two parts which fit together on cylindrical surfaces, the axis of these cylindrical surfaces being at right angles to the polar axis and passing through the center of the bearing. Lugs and holding-bolts serve to keep the two portions together. This device allows the bearings to adjust themselves, in altitude, to the polar axis. The adjustment of the bearings to the axis in azimuth can be accomplished by having a stout pin on the under side of the lowest section of the bearing, which turns in the base-plate. Such a system would make the bearing a universal joint through small arcs, and wholly self-aligning. Bolts for holding the bearing to the pier should of course be provided.

The bearing at the lower end of the polar axis can be made to take the thrust and at the same time be wholly self-aligning. This may be done by extending the cylindrical portions upward around the end of the axis so as to contain the line of thrust.

When both ends of the axis are supported from the same base-casting, the bearings are usually fixed. Even in that case there would probably be some advantage in using self-aligning bearings.

While the subject of this paper properly belongs to a different Section of the Association, it is perhaps of special interest to astronomers.

MT. HAMILTON, CALIFORNIA, November 30, 1903.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter, May 7, 3 ^h 50 ^m A.M.	Last Quarter, June 5, 9 ^h 53 ^m P.M.
New Moon, " 15, 2 58 A.M.	New Moon, " 13, 1 10 P.M.
First Quarter, " 22, 2 19 A.M.	First Quarter, " 20, 7 11 A.M.
Full Moon, " 29, 12 55 A.M.	Full Moon, " 27, 12 23 P.M.

The Sun reaches the solstice and summer begins on June 21st at about 1 P.M., Pacific time.

Mercury on May 1st is an evening star, setting about an hour and one half after sunset. It passed greatest east elonga-

tion on April 21st, and is drawing nearer to the Sun, so that it can be seen for only a few days at the beginning of the month. It passes inferior conjunction on the morning of May 13th, becoming a morning star, and moves rapidly away from the Sun, reaching greatest west elongation on June 8th. Its distance from the Sun is then $23^{\circ} 46'$, but it is 9° south of the Sun, and therefore the interval between the rising of the planet and of the Sun is not as great as it is at some greatest elongations. However, during all except the last few days of the month *Mercury* rises an hour or more before the Sun, and may be seen in the morning twilight if weather conditions are favorable. It is in close conjunction with *Mars* on May 9th, $0^{\circ} 21'$ north, and with *Venus* on May 22d, $1^{\circ} 53'$ south, but both conjunctions occur when the planets are rather too near the Sun to be made out without a telescope.

Venus is still a morning star, but is gradually drawing too near the Sun to be conspicuous. On May 1st it rises only forty minutes before sunrise, on June 1st only thirty-two minutes before, and on June 30th only eleven minutes before. It will be a very difficult matter to see *Venus* without a telescope after June 1st. It will pass conjunction and become an evening star during the night of July 7-8th. *Venus* and *Mars* are in conjunction at about midnight on June 18th, the former being $0^{\circ} 35'$ north, but, like the *Mercury* conjunctions, the planets are too near the Sun for easy view.

Mars is too near the Sun throughout the two-months period for naked-eye observations. At the beginning of May it is an evening star, setting only a little more than a half-hour after sunset. It passes conjunction with the Sun on May 30th and becomes a morning star. At the end of June it rises about forty minutes before sunrise. It will, however, scarcely be possible for it to be seen without a telescope, as it is at the same time at its maximum distance from the Earth for this revolution (238,000,000 miles), and consequently at its least brightness. For a year more, until it comes to its next opposition in 1905, it will gradually grow brighter, but it will not be at all conspicuous during the rest of 1904.

Jupiter passed conjunction with the Sun at the end of March, and by May 1st rises about an hour before sunrise. The interval increases, so that at the end of June it rises half

an hour after midnight. Its brightness is so great that it may be made out at the beginning of the two-months period. During May and June it moves 11° eastward and 4° northward in the eastern part of the constellation *Pisces*, rather a barren region of the sky.

Saturn is gradually moving around to a more convenient position for observation. It rises a little before 2 A.M. on May 1st, at about midnight on June 1st, and before 10 P.M. on June 30th. It is in the constellation *Capricorn*, and moves about 1° eastward until June 1st, and then begins to retrograde, reaching a position at the end of June almost the same as it had on May 1st.

Uranus is now getting into position for evening observation, rising before 11 P.M. on May 1st and at about half-past 6 on June 30th. It is in opposition on June 19th, and is then above the horizon throughout the night. It retrogrades or moves westward about 2° , and is in the western part of *Sagittarius*, a little north and west of the group known as "the milk-dipper."

Neptune is in the western sky in the evening, in the constellation *Gemini*. It reaches conjunction with the Sun on June 27th.

VARIABLE STARS.

BY ROSE O'HALLORAN.

V Cassiopeiæ.

1903. Eleven observations, distributed between the 17th of August and the 14th of September, showed that in a 4-inch lens this variable was on the verge of invisibility, which is generally the stage of 12th magnitude. Fainter stars are undiscernible except on very clear, calm nights. September 16—Much more distinct. October 12—Between 9th and 10th magnitude, and distinctly brighter than the star just adjacent to it.

Y Cassiopeiæ.

The last maximum of this star was observed as follows:—1903. August 27—Scarcely of 11th magnitude, but distinctly seen below *b*, classed as 10.2. August 31, September 2, 8, 9—Ditto. September 13—Nearly equal to *b*. September

16—Fully equal to *b*. September 29—About 9.7; brighter than *b*; equal to *m* and *n*. October 28—Brighter than *b* or *d*; equal to *m* and *n*. November 6—Equal to *b*.

W Cassiopeiæ.

1903. June 24, 26, 29, 30; July 1, 2, 3, 6, 13, 19—About 10th magnitude. July 23—Declined to 10.3 magnitude. July 31—10.6 magnitude. August 16, 23—11th magnitude. August 29, September 2—11.3 magnitude. September 9, 14—Not discernible in haze. September 16—12th magnitude. September 29, October 18, November 6—Invisible.

In the *Companion to the Observatory* the minimum was predicted for October 18th. On this occasion it was probably fainter than 12th magnitude.

W Lyræ.

The last maximum occurred more than a month in advance of the predicted date, October 30th, as follows:—

1903. July 6—Not visible with high power in clear moonlight. July 11—Scarcely as bright as 12th magnitude, but distinct in high power. July 24, 25—Of 11.5 magnitude: fully equal to *t*. August 2, 5—Equal to *p*, of 9.4 magnitude. August 22—Of 8.7 magnitude; between *e* and *a*. September 6—Of 8.1 magnitude; brighter than *a*, equal to *n*. September 23—About two tenths brighter than *n*. October 5—In moonlight *W*, *a*, and *n* seem equal. October 13—The variable seems two tenths dimmer than *n*. October 18—Scarcely of 9th magnitude; between *a* and *p*, but nearer to latter. November 1—Equal to *p*. December 23—Scarcely of 12th magnitude.

1904. January 5—Not visible; morning clear. January 20—Ditto; probably less than 12th magnitude.

R Cygni.

1903. From June 25th to August 29th *R Cygni* was looked for in vain, but on October 18th was seen to be about 8.5 magnitude. November 1—Of 9th magnitude.

S S Cygni.

1903. Two maxima of *S S Cygni* were observed between July 23d and September 14th. July 23, 9.25 P.M.—Brighter than *a* or *c*; less than *b*. July 24, 9 P.M.—Nearer to *b*. July 25, 9.15 P.M.—Between *c* and *b*; nearer to *c*. July 30, 8.40 P.M.—Nearly equal to *b*; much brighter than *c*; night dim.

August 1, 8.40 P.M.—Not so near *b*, but brighter than *c*.
August 2, 8.35 P.M.—Decreased, but still brighter than *c*.
August 5, 8.30 P.M.—Less than *b*, *c*, or *a*, but brighter than *d*. August 16, 17, 23, 29, 31; September 2, 8—No longer identifiable among the stars of 12th magnitude near its place.
September 9, 7.45 P.M.—Less than *b*; equal to *a* and *c*, which look alike to-night. September 13, 8 P.M.—Two tenths brighter than *a*. September 14, 7.50 P.M.—Still brighter than *a* or *c*. This constellation was lost to view after this date.

X Aquilæ.

1903. From June 25th to November 1st this variable was looked for on twenty-four clear evenings, but the faintest glimmer was undiscernible within some minutes of the place it occupies when visible. August 17th, the date of predicted minimum, was included. It was probably fainter than 12th magnitude.

R Tauri.

1903. December 8—Of 12th magnitude. December 22—11.5 magnitude. December 25, 26—10.5 magnitude.

1904. January 4—About 8.5 magnitude. January 6—Of fully 8th magnitude. January 11—About 7.7 magnitude. January 14—Seems slightly decreased. January 17—Of 8th magnitude. January 20—Rather brighter than 8th magnitude. January 22—Slightly decreased. January 23—Further decreased; scarcely of 8th magnitude. The previous maximum occurred in March, 1903.

(FORTY-SIXTH) AWARD OF THE DONOHUE
COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to M. BORRELLY, astronomer, Marseilles, France, for his discovery of an unexpected comet on June 21, 1903.

The Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON.

REPORTS OF OBSERVATORIES.

Manuscript intended for this department should be sent to FRANK SCHLESINGER, Yerkes Observatory, Williams Bay, Wis.

NAVAL OBSERVATORY, WASHINGTON, D. C.

During the year 1903 the following changes have taken place in the personnel:—

Mr. T. I. KING, assistant astronomer, was transferred to the Nautical Almanac Department December 1st, at which date Mr. J. C. HAMMOND was promoted to fill the vacancy thus caused.

The instruments have been used as follows:—

The 6-inch transit-circle was devoted to the routine observations of the Sun, Moon, and planets up to September 4th, when the work was transferred to the 9-inch transit-circle, thus permitting the consideration of certain changes and additions to the instrument.

The 9-inch transit-circle, after the completion of extensive repairs and improvements, was put into commission September 3, 1903, and has since been used for the fundamental determination of the Right Ascension and Declination of the Sun, Moon, planets, and the stars of NEWCOMB'S Fundamental Catalogue, GILL'S Zodiacal Catalogue, and the Zodiacal Catalogue of the U. S. Nautical Almanac Office, now in press.

A new clock by RIEFLER, of Munich, in an air-tight glass case, with nickel-steel pendulum and electrical winding, was installed September 1st, and has been used since that date as the standard sidereal clock.

The prime vertical transit-instrument has been devoted to continuing observations for the determination of aberration, nutation, and variation of latitude and to the determination of the declinations of 390 miscellaneous stars.

The altazimuth instrument has been devoted to a determination of the latitude of the observatory and the declinations of 350 standard stars.

Photographs of the Sun have been obtained with the photoheliograph on every clear day.

The equatorials have been devoted to measurements of

the diameters of the planets, and to the observations of the satellites, asteroids, comets, and occultations. Photography has been used in detecting the location of most of the asteroids which have been observed.

During the year 1903 the following volumes have been published: Volume III, *Publications of the U. S. Naval Observatory*, Second Series, containing observations of *Eros* and the reference-stars, observations of zodiacal stars and prime vertical observations 1882-1884; Volume V, *Meteorological Observations and Results*, 1893-1902. Volume IV is now in press.

Good progress has been made on the formation of the Catalogue of the Astronomische Gesellschaft Zone, — $13^{\circ} 50'$ to — $18^{\circ} 10'$, as well as on the cataloguing of the Washington zones 1846-1852.

The practical naval features of the observatory work are seen in the regular publications of the American Ephemeris and Nautical Almanac, and the purchase, trial, and issue to the naval service of chronometers, watches, sextants, telemeters, binoculars, surveying and photographic outfits, and all navigational instruments, except compasses. The time-service maintained in connection with the chronometer service sends out daily, except Sundays and holidays, telegraphic noon-signals that reach all points in the country, correcting some 40,000 clocks, and dropping sixteen time-balls.

The following articles by members of the Observatory staff have appeared during the year 1903:—

Elements and Ephemeris of Comet *a* 1903 (GIACOBINI), by H. R. MORGAN and ELEANOR A. LAMSON (*A. J.* 530 and *A. J.* 531-532).

Observations of Heliumeter Comparison-Stars, by M. UPDEGRAFF and J. C. HAMMOND; Observations of Minor Planets, by J. C. HAMMOND; Observations of Comet *b* 1902 (PERRINE), by C. W. FREDERICK and W. W. DINWIDDIE (*A. J.* 533).

Observations of the Declinations of *Vesta*, by GEORGE A. HILL; Observations of the Right Ascensions of *Vesta*, by EVERETT I. YOWELL (*A. J.* 534).

Observations of Comet 1900 II, by GEORGE K. LAWTON (*A. J.* 535).

Observations of Comet *a* 1903 (GIACOBINI), by C. W.

FREDERICK; Observations of TURNER's *Nova* (2387 *Geminorum*), by C. W. FREDERICK; Photographic Observations of the Minor Planet (60) *Echo*, by G. H. PETERS; Photographic Observations of Minor Planets, by G. H. PETERS (*A. J.* 537-538).

Observations of Minor Planets, by J. C. HAMMOND (*A. J.* 540-541).

Observations of the Satellite of *Neptune* and Comet *d* 1902 (GIACOBINI), by W. W. DINWIDDIE; Observations of Minor Planets, by J. C. HAMMOND; Observations of Comet *b* 1902 (PERRINE), by C. W. FREDERICK (*A. J.* 542-543).

Observations of BROOKS's Comet 1889 V, by C. W. FREDERICK; Observations of Minor Planets, by J. C. HAMMOND (*A. J.* 547).

Observations of Comets and Minor Planets, by T. I. KING; The Instrumental Constants in Equatorial Work, by C. W. FREDERICK (*A. J.* 552).

Chronometer-Rates, by Lieut.-Commander E. E. HAYDEN (*Proceedings Naval Institute*, Vol. 29, No. 3).

The Pivots of the 9-inch Transit-Circle of the Naval Observatory, by W. S. EICHELBERGER (*Astron. and Astroph. Soc.*, December, 1903).

C. M. CHESTER, *Rear Admiral, U. S. N.,*
Superintendent Naval Observatory.

KIRKWOOD OBSERVATORY, BLOOMINGTON, IND.

As this observatory is a part of Indiana University, it seems necessary at present that the major part of the time and energy of the corps of instructors be devoted to teaching. This affects in a serious manner the quantity, certainly, and perhaps the quality, of research work done here. However, at least the first half of every clear night is devoted to work with the telescopes. A part of this time is used by students more or less advanced, whose work, though done seriously, is in the main that of amateurs.

During the past two years we have measured about three hundred pairs of double stars, which have been selected from those noted as double by observers while making the A. G. catalogues, and which have not been hitherto measured. The

measures of two of these lists have already been published, and two other lists are now in manuscript. The measures were made with the 12-inch refractor to which is attached a micrometer by WARNER & SWASEY. With the same instrument we obtained a large number of positions of Comet *d* 1902 and Comet *a* 1903.

A mounting for a 15-inch reflector, the mirror of which was kindly loaned us by Mr. O. L. PETITDIDIER, of Chicago, has just been completed by the department. With this instrument a series of photographs of nebulae and star-clusters has been made. With a portrait-lens of five inches aperture and with a small "tintype" lens a fairly complete series of photographs of BORRELLY'S Comet was obtained. Using a color-screen, we have succeeded in making with the refractor quite excellent photographs of the Moon.

JOHN A. MILLER, *Director*.

CHAMBERLIN OBSERVATORY, DENVER, COLO.

During the year 1903 only comet observations were made, the time of the director of the observatory being largely consumed by administrative work in connection with the University of Denver.

H. A. HOWE, *Director*.

THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN
INSTITUTION, WASHINGTON, D. C.

Bolographic studies of the spectrum of the Sun and the provision of a large horizontal telescope to be used for studies of special portions of the solar radiation have been the distinguishing features of the work of the Astrophysical Observatory during the past year. Results of uncommon interest have been reached in the bolographic work of the past twelve months, and especially in the studies of the absorption of the solar rays by our atmosphere.

Briefly this has shown that the Earth's atmosphere, so far as it can be observed here, has been more opaque than usual within the present calendar year, so much so as to reduce the direct radiation of the Sun at the Earth's surface by about ten per cent, on the average, throughout the whole visible and infra-red spectrum, and by more than double this amount in

the blue and violet portions of the spectrum. This alteration of the transparency of the air has not, however, been confined to the region of Washington.

Another interesting observation is that determinations of the rate of solar radiation outside the Earth's atmosphere might appear to indicate that there has been a decrease of the solar radiation itself since March 26, 1903; but I refer to this with hesitation, as I have elsewhere observed that it is scarcely possible to be certain of the accuracy of results of this sort when based on observations near sea-level. The value of a solar observatory at a high altitude, to which I referred last year, can hardly be overestimated.

A new determination of the temperature of the Sun, based on the distribution of the solar radiation in the spectrum, has yielded a result of $5,920^{\circ}$ of the centigrade scale above absolute zero.

For the purpose of the special study of the nature of sun-spots, the absorption of the solar gaseous envelope, and for other observations requiring a large solar image an equipment including a horizontal reflecting telescope of 140-foot focus and 20-inch aperture and a cœlostast of improved construction to furnish at all times a 20-inch horizontal northerly directed solar beam has been provided. The form of cœlostast employed seems so well suited to solar work that this large instrument will be exhibited by the observatory at the Louisiana Purchase Exposition in 1904. Provision has been made in connection with the long-focus telescope to churn the air traversed by the beam from the cœlostast to the focal image after the manner described in my last year's report. It is hoped that this installation will have yielded results of interest before another year.

On the whole, the work of the Astrophysical Observatory during the past year has been quite as productive of results of interest as during any former year of its existence, especially in showing a notable variation of atmospheric transparency which is likely to have affected climate and the growth of vegetation over a considerable part of the Earth's surface, and in the studies of atmospheric absorption and those relating to the solar constant, to which I have referred, there seems renewed promise of progress toward the goal "foretelling by

such means those remoter changes of weather which affect harvests," which is one of the great aims had in view in the foundation of the observatory.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

CINCINNATI OBSERVATORY, CINCINNATI, OHIO.

The work of this observatory during 1903 has been along the same lines as in the year previous. Observations for the variation of latitude were carried on with as great regularity as the weather would permit, 1,490 pairs having been obtained. The reobservation of the stars of PIAZZI's catalogue north of the equator with the meridian-circle was practically completed. It is hoped during the current year to publish the results.

Last summer the 11-inch equatorial, originally purchased by Professor MITCHEL, was dismantled. For nearly thirty years it stood on Mount Adams, a high prominence overlooking the city, and named in honor of JOHN QUINCY ADAMS, who delivered the oration at the laying of the corner-stone of the Cincinnati Observatory. For thirty years more the telescope has stood upon Mount Lookout, six miles northeast of the city. It is hoped soon to remount this historic instrument, the oldest of any considerable size in the Western Continent.

In the mean time the observatory has purchased of the Alvan Clark Corporation a new 16-inch equatorial, which will be installed early in the year. It is then expected to take up some lines of extra-meridian work.

J. G. PORTER, *Director.*

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASS.

East Equatorial.—Nearly all of the observations with this instrument have been made by Professor O. C. WENDELL, and have been of the same general character as in previous years. The errors of observation have an average value of three or four hundredths of a magnitude. Deviations of a tenth of a magnitude generally indicate real changes in the star measured. The effect of color also seems less troublesome than with visual observations. About two thousand measures have been made of stars suspected of variability by other observers. An attempt is made to measure, every year, all stars which

vary more than half a magnitude an hour, on three nights when increasing in light, and on three when decreasing in light. About six thousand measures have been made of such objects. Seven hundred measures have also been made with a second photometer adapted to the comparison of stars too near together to be measured with the first instrument. The same instrument has been used in the photometric measurement of *Jupiter's* satellites while undergoing eclipse. Observations of variable stars of long period throughout their changes, and the reduction of the results to the scale of the meridian photometer have been continued.

Similar observations of variables and comparison-stars have been made with the *West Equatorial*. With it 1,724 estimates of variables and 399 of comparison-stars have been made by Miss CANNON. Three thousand three hundred and ninety-five estimates of variables, and 323 estimates of comparison-stars have been made by Mr. CAMPBELL with the naked eye, field-glass, and a 5-inch portable telescope. Some estimates of faint variables and photometric measurements of double stars were also made by Mr. CAMPBELL during the month of August, with the *East Equatorial*.

Meridian Circle.—The only important work of this instrument during the year has been the determination of clock-error. All the columns of the catalogue of stars belonging to the zone $-9^{\circ} 50'$ to $-14^{\circ} 10'$ are now provisionally complete, except that current numbers are not yet assigned to the stars. The work of re-computing particular observations, in cases of large discrepancy, is also very nearly finished.

12-inch Meridian Photometer.—The principal work has been the completion of observations undertaken in previous years, and the measurement of all the Durchmusterung stars in zones $10'$ wide, north of Declinations -5° and -15° . A beginning has been made of the observations of stars in similar zones south of $+5^{\circ}$, $+15^{\circ}$, and $+25^{\circ}$. This work will supplement that already completed at Declinations -20° , -10° , 0° , $+10^{\circ}$, etc. Measures have also been made of sequences of stars from the eighth to the thirteenth magnitude, in twenty-three coarse clusters, to determine the absolute magnitudes of the components of these objects. By interposing a shade-glass so as to reduce the light of the star, any star however bright

could be measured. Another modification of the instrument permitted surfaces to be measured.

Henry Draper Memorial.—Eight eclipses of *Jupiter's* satellites, and five occultations, have been successfully photographed with the 11-inch Draper telescope. Four variable stars have been found by Mrs. FLEMING, and one by Miss BRESLIN, from the examination of the Draper photographs. Among other photometric investigations of plates, it was found that a reduction of temperature from 70° to 0° F. increased the sensitiveness of plates by about half a magnitude. Photographic charts have been made here of the regions of asteroids which have not been observed elsewhere during the last three years. Several asteroids have thus been found, but owing to the faintness of the greater portion of these objects the 8-inch Draper telescope, which was the instrument employed, is hardly large enough for this work.

Boyden Department (Arequipa).—Measures have been made on 21 nights, with the meridian photometer, in extending to the South Pole the system of bright standard stars, one in each ten degrees square. Many measures were made with the Rumford photometer attached to the 13-inch Boyden telescope. Notwithstanding its faintness, the variations in the light of *Eros* have thus been measured by Professor BAILEY from March 30th to August 19th. Excellent curves have been obtained which show a variation in the range from about half a magnitude to a magnitude. Observations of fifty southern variables have been made, besides a careful study of their comparison-stars.

Bruce Photographic Telescope.—The number of photographs taken with the Bruce photographic telescope was 413. Although these plates are difficult to handle and liable to be broken, owing to their size, which is 14 by 17 inches, yet they are proving extremely useful, since by their aid stars may be studied which are much too faint to be photographed with our other instruments. The scale also permits positions to be determined much more accurately than with smaller instruments. Forty-two of these plates had exposures of one hour, and showed the spectra of the stars; the remainder were chart-plates, of which 17 had exposures of four to five hours, 66 of one hour, 166 of ten minutes; 87 were of the planet *Eros*,

and 35 were miscellaneous. Mr. FROST, from an examination of 18 photographs, found 37 nebulae not contained in DREYER's catalogue. On one plate he counted 10,926 stars in one square degree.

Miscellaneous.—The reduction of the observations made by the late Professor ROGERS with the meridian-circle, during the years 1879 to 1883, is being continued by Miss BOND. Mrs. FLEMING has not been able for some time to continue the classification of spectra for the Southern Draper Catalogue. Arrangements have now been made so that she is doing this work at home in the evening. A stereocomparator has been constructed and gives satisfactory results. The Revised Harvard Photometry, containing about nine thousand stars, is now approaching completion. All stars in any part of the sky and of the magnitude 6.5 and brighter in any of our photometric catalogues are included. The anonymous gift of 1902 has been of the greatest service; it will provide two reflectors of twenty-five inches aperture, one for use on the northern and the other on the southern stars, and has given us a fire-proof wing to the building already used for storing and studying the photographs. The cost of the entire building and wing was only about \$20,000, and two similar buildings would provide for a much needed new library for the observatory, computing-rooms, photographic laboratory, and a workshop.

EDWARD C. PICKERING, *Director.*

THE WASHBURN OBSERVATORY, MADISON, WIS.

During the year 1903 the 40^{cm} equatorial telescope was employed by the Director in the following series of observations: (a) Micrometric observations for the determination of the parallax and proper motion of *Nova Persei*. This series, commenced immediately after the appearance of the *Nova*, will be continued at epochs of maximum and minimum parallactic effect so long as is feasible. (b) Micrometric observations of a selected list of binary stars known to be in relatively rapid motion. This work is in continuation of the observations contained in *Publications of the Washburn Observatory* (Vol. X). (c) The remeasurement of a list of wide double stars first observed a half-century since by the STRUVES. (d) Experiments

to determine the adaptability of the telescope to celestial photography as a substitute for the micrometer.

The amount of work accomplished along these several lines has been considerably restricted by unfavorable atmospheric conditions, and in even greater measure by a large increase in the purely academic duties of the Director. Although no clerical assistance is available in connection with this work, the reductions of all observations have been completely made, and the observations of the binary stars are ready for publication. The observations of *Nova Persei*, while individually reduced, still require a discussion that can be given only when the series is complete.

The observations above noted under the rubric (c) were undertaken with a view to the determination of the proper motions of faint stars (8 to 12 magnitude), and the observing list is intended to include all stars of this character that have been compared by the STRUVES with bright stars of known proper motion. For a provisional account of the results already obtained, together with some discussion of their bearing upon current theories of the constitution of the stellar system, reference may be made to the *Astronomical Journal*, No. 558.

The meridian-circle of 12.2^{cm} aperture was employed during the year 1903 by Mr. A. S. FLINT in observations for the determination of stellar parallax. These observations, beginning July 15, 1898, constitute a second series substantially similar to the first series of parallax determinations, contained in *Publications* of the Washburn Observatory (Vol. XI), save that in their conduct a Repsold transit-micrometer has been employed. The reader may consult the *Astronomical Journal*, No. 470, for an account of the observer's earlier experience with this micrometer and with the peculiar system of slat screens employed for diminishing the apparent magnitudes of the stars observed. The result of five years' additional experience is on the whole favorable to the apparatus, when employed, as is here done, with close parallel threads, between which the star's image is held during transit. After some experimentation the observer has adopted 10" as approximately the most convenient distance between these threads.

The observing list of stars whose parallaxes are to be determined is made up as follows:—

Stars brighter than magnitude 1.5	1
Stars between magnitudes 1.5 and 2.5, inclusive	41
Stars between magnitudes 2.6 and 3.1, inclusive	26
Fainter stars of large proper motion	36
Binary stars	18
Miscellaneous stars	2
Total	124

It was the original intent to include in this list all stars between the magnitudes 1.5 and 2.5 that were within the reach of the instrument, and the number 41, above given, represents approximately two thirds of all stars of this class in the entire sky.

Observations of 66 stars of the foregoing list are now completed, with an average of 73.4 observations per star, including in most cases two comparison-stars for each star whose parallax is to be determined. Early in the progress of the work preliminary solutions were made in the case of six parallax stars, having an average of 53 observations per star, and from these it appears that the average probable error of a parallax thus determined is $\pm 0''.032$. The individual parallaxes thus determined were $+0''.01$, $+0''.04$, $+0''.05$, $+0''.26$, $-0''.02$, $-0''.01$.

Through the courtesy of the trustees of the Gould Fund of the National Academy of Sciences a grant of \$400 has become available during the past year in aid of the reduction of these observations, and has considerably facilitated the work. The present state of the reductions is represented by the statement that, for the observations already made, approximately one half of the computing required to produce the absolute terms of the resulting observation equations is completed.

The parallax observations being in an advanced state, Mr. FLINT undertook, in October, 1903, and is now actively carrying on, the determination of the positions of a list of stars observed by the Director as comparison-stars in the work above designated (*c*). These are for the most part stars of moderate brightness, for the determination of whose proper motions modern observations are greatly needed.

Aside from the current determination of time, the transit-

instrument and the small equatorial telescope of the observatory have been used only for purposes of instruction.

March 10, 1904. *GEORGE C. COMSTOCK, Director.*

INTERNATIONAL LATITUDE STATION, UKIAH, CAL.

The programme of the International Geodetic Association for observing variations of latitude was continued throughout 1903 without modification or interruption. Dr. SCHLESINGER's connection with the station ceased on April 30th, and mine began on February 1st. Very good observing weather prevailed during nearly the entire year. The longest intervals without observations were nine nights in January, and again nine nights in December. December, however, yielded a unique record—sixteen complete (no incomplete) nights' work. Between November 29 and January 21, 1904, an unbroken record of twenty-eight complete nights was obtained. The total number of pairs observed was 2,655, which exceeds by 552 pairs the best previous record. The distribution by months is as follows:—

	Pairs.		Pairs.
1903. January	155	1903. July	209
February	257	August	222
March	161	September	200
April	309	October	238
May	261	November	172
June	215	December	256

During the three months that Dr. SCHLESINGER and I observed together the nights were about equally divided between us, the plan being to determine the personal difference between the two observers. For this purpose 650 pairs were obtained, and a preliminary reduction of these gives a difference between results of the two observers of but $0''.01$, $\phi_s - \phi_T = + 0''.01 \pm 0''.01$.

SIDNEY D. TOWNLEY.

VASSAR COLLEGE OBSERVATORY, POUGHKEEPSIE, N. Y.

During the past year the observatory of Vassar College has been occupied with the reduction of photographic plates covering the region about the North Pole. With the grant from the Carnegie Institution, two computers were engaged,

who are still employed, and during the summer months the number was increased by two, one of whom had had considerable experience in such computation.

The reduction of the separate plates and their interadjustment have been completed, and the final catalogue is nearly ready. There remains still the determination of the proper motions, for which a large amount of material has already been collected. Of the stars on the plates, 31 are found in SCHWED, 165 in CARRINGTON, 78 in the observations of FABRITIUS at Kiev, and 60 in the Greenwich observations for 1899 and 1900. Scattering observations are found in a number of other catalogues. With but few exceptions, the proper motions of these stars have never been determined.

During the past year a photometer, with a photographic wedge after the Harvard pattern, has been added to the equipment of the observatory, and has been used by Professor WHITNEY for observing variable stars.

The regular work of observing asteroids and comets has been omitted this year, since the computing force has been exclusively occupied with the plate-work.

The instruction which forms the principal work of the observatory force has continued as heretofore.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

DEFINITIVE ORBIT OF THE SPECTROSCOPIC BINARY ι PEGASI.†

This binary was discovered by Director CAMPBELL and announced by him in the *Astrophysical Journal* for May, 1899. The spectrum is of Type F, with fairly good lines. The determination of the orbit is made to depend upon forty-three plates, comprising all the plates of this star which have been taken with the Mills spectrograph, with the exception of a few of poor focus or insufficient exposure, which have been rejected. The formulæ and methods used are those of LEHMANN-FILHÉS [*A. N.* 3242], with the addition of a sixth unknown for the change in the assumed velocity of the system.

The preliminary orbit adopted as the basis of the solution is as follows:—

PRELIMINARY ELEMENTS.

$$\begin{aligned}\text{Velocity of system} &= -3.91 \text{ km} \\ T &= 1899 \text{ June } 15.515 \\ &= \text{Julian Day } 2414821.515 \\ e &= 0.0205 \\ \omega &= 272^\circ.732 \\ \log \mu &= 9.78864 \\ \log \kappa &= 1.67574 \\ \text{Period} &= 10^d.2132\end{aligned}$$

A second solution was found to be necessary, inasmuch as the agreement between the ephemeris from the first solution and substitution of the values of the unknowns in the equations of condition was not sufficiently close, due to omitted terms of the second order in the differential coefficients. The values of

* Lick Astronomical Department of the University of California.

† Abstract of the *L. O. Bulletin*, No. 53.

the unknowns derived from the second solution, with their probable errors, are as follows:—

VALUES OF UNKNOWNNS, SECOND SOLUTION.

$\delta V = -0.09$	$\pm 0.11 \text{ km}$
$\delta T = -0.200$	$\pm 0.352 \text{ days}$
$\delta \mu = +0.00000007$	± 0.00000407
$\delta \kappa = +0.0327$	± 0.1523
$\delta \omega = -0.1230$	$\pm 0.0240 \text{ radians}$
$\delta e = -0.00008$	± 0.0040

FINAL ELEMENTS.

$V = -4.12$	$\pm 0.11 \text{ km}$
$T = 1899 \text{ June } 14.966$	$\pm 0.352 \text{ days}$
$= \text{J. D. } 2414820.966$	
$e = 0.0085$	± 0.0040
$\omega = 251^\circ.807$	$\pm 1^\circ.373$
$\log \kappa = 1.68117$	± 0.00014
$\log \mu = 9.7890216$	± 0.0000029
$\mu = 35^\circ.2488$	$\pm 0^\circ.0002$
Period = 10.21312	$\pm 0.00006 \text{ days}$
$a \sin i = 6.740,000 \text{ km}$	

The sum of the squares of the weighted residuals has been reduced from 51.14 to 26.25.

The probable error of a single plate as derived from this solution is $\pm 0.56 \text{ km}$. The relatively large probable errors in the values of T and ω arise from the fact that the orbit is nearly a circle, the eccentricity being only $+0.0085$. On the other hand, inasmuch as the observations cover two hundred and nineteen complete revolutions of the star, the period is determined with considerable accuracy. The largest residual is -2.14 km ; the range of velocity is from $+43.7 \text{ km}$ to -52.1 km per second.

HEBER D. CURTIS.

March, 1804.

RECENT MEASURES OF ϵ *HYDRÆ*, AB.

Measures on three nights of SCHIAPARELLI's rapid binary system, ϵ *Hydræ*, AB, give the following mean result:—

$$1904.047 \quad 147^\circ.2 \quad 0''.25.$$

The position for this epoch derived from my preliminary elements* is $150^\circ.9$, $0''.25$, leaving the residuals (O—C).

* See these *Publications*, Vol. XV, p. 84, and *L. O. Bulletin*, No. 36.

— $3^{\circ}.7 \pm 0''.00$. These correspond to a displacement of the companion-star of less than $0''.02$ in arc.

R. G. AITKEN.

March, 1904.

A NEW COMPANION TO Σ 1506, AND A NEW NAKED-EYE DOUBLE STAR.

Two of the new double stars recently discovered with the 36-inch telescope are of sufficient interest to be noted at this time. One is a naked-eye star in *Monoceros*, whose position for 1900.0 is R. A. $6^h 10^m 40^s$; Decl. — $9^{\circ} 0'$; the other is the companion to the wide pair Σ 1506, which I find to be a close double. The results of my measures of these stars are:—

Star.	Date.	Angle.	Distance.	Magnitudes.	Nights.
1	1904.05	$158^{\circ}.2$	$0''.23$	6.6 — 6.6	4
2 {	1904.08	55.5	0.20	10.0 — 10.0	1 BC (new)
	.08	216.1	11.12	7.3 — 9.5	1 A and BC (= Σ 1506)

March, 1904.

R. G. AITKEN.

HONORS FOR DIRECTOR CAMPBELL.

Professor W. W. CAMPBELL has been elected a Foreign Member of the Società degli Spettroscopisti Italiani. This society consists of thirty Italian members and thirty foreigners. Membership in it by a foreigner is a signal honor.

Professor CAMPBELL has also been requested to serve on an honorary committee presided over by the Minister of Public Instruction for France, whose purpose is to forward the project for erecting a monument to the eminent astronomer JEROME LALANDE, at Bourg, the place of his birth.

R. G. A.

GENERAL NOTES.

At the meeting of the American Association for the Advancement of Science held in St. Louis, four papers upon astronomical subjects were presented before Section A, Mathematics and Astronomy. The papers were:—

The Rotation Period of the Planet *Saturn*: G. W. HOUGH, Director of Dearborn Observatory, Evanston, Ill.

Facilities for Astronomical Photography in Southern California: E. L. LARKIN, Director of Lowe Observatory.

The Supporting and Counterweighting of the Principal Axes of Large Telescopes: C. D. PERRINE, Lick Observatory.

A New Type of Transit-Room Shutter: DAVID TODD, Director of Amherst College Observatory.

The fifth meeting of the Astronomical and Astrophysical Society of America was held in St. Louis during Convocation week, in affiliation with the American Association for the Advancement of Science. Professor SIMON NEWCOMB was re-elected President of the Society. The list of papers presented, abstracts of which may be found in *Science* for February 19th, was as follows:—

The Prediction of Occultations of Stars by the Moon: G. W. HOUGH.

The D. O. Mills Expedition: W. W. CAMPBELL.

The Sun's Motion Relative to a Group of Faint Stars: G. C. COMSTOCK.

The Absorption of the Solar Radiation by the Sun's Atmosphere: F. W. VERY.

Borrelly's Comet: SEBASTIAN ALBRECHT.

The Pivots of the Nine-Inch Transit-Circle of the U. S. Naval Observatory: W. S. EICHELBERGER.

A Short Sketch of the Progress of Astronomy in the United States: M. S. BRENNEN.

The *Eros* Parallax Photographs at the Goodsell Observatory: H. C. WILSON.

The following notes have been taken from recent numbers of *Science*.

The grant of the Carnegie Institution to the Department of Astronomy of Princeton University has been increased to \$1,200. This money is to be used in determining the brightness of certain standard stars.

The death is announced of M. CALLANDREAU, member of the Paris Academy of Sciences in the section of Astronomy.

Professor HERMANN STRUVE, Director of the Observatory at Königsburg, has been appointed Director of the Observatory at Berlin.

Sir WILLIAM HUGGINS, President of the Royal Society, celebrated his eightieth birthday on February 7th.

An observatory has been established at Lagreb, the capital of Croatia (Hungary), and is under the direction of Professor OTTO KUCERA. It has equatorials of 6.4 and 4.25 inches aperture, and it is proposed to observe the Sun, planets, and variable stars.

The next meeting of the Astronomical and Astrophysical Society of America will be held, in affiliation with the American Association for the Advancement of Science, at Philadelphia, during Convocation week, 1904-1905.

The *Astronomical Journal* No. 555 contains an important article entitled "Definitive Orbit of Comet 1845 III," by HENRY A. PECK. This was a naked-eye comet and at the time of visibility it was thought that it might be a return of the famous comet observed by TYCHO BRAHE in 1596. Its orbit was computed by D'ARREST, who found that the observations could be equally well satisfied by a parabola, an hyperbola, and an ellipse of 249 years period.

Mr. PECK concludes, however, "that the complete examination of the observations substantiates the parabolic orbit of D'ARREST, while it shows that his ellipse must be abandoned as being contrary to fact."

The Carnegie Institution has granted the sum of \$500 to Professor F. P. LEWIS, of the University of California, for the purpose of carrying on spectroscopic work. Professor LEWIS has already published some interesting results of investigations of the spectra of gases under different physical conditions and upon the spectra of mixed gases. The grant from the Carnegie Institution will enable him to purchase

improved apparatus and to carry on the experiments upon an enlarged scale.

Dr. LUDENDORFF, of Potsdam, has published (*A. N.* 3918-3920) some interesting results of investigations of the brightness of *e Aurigæ*. The fluctuations in brightness of this star were first discovered in 1821, but the period was not apparent, and it has been classed as an irregular variable. In the fall of 1902 it was found at Potsdam that this star is a spectroscopic binary of probably very long period. Dr. LUDENDORFF finds, from investigation of all the available observations, that this is an *Algol* variable system, composed of two bright stars revolving in a period of $54\frac{1}{4}$ years, and eclipsing each other every $27\frac{1}{8}$ years. The star remains at maximum brightness for over twenty-five years, declines to minimum in 207 days, remains at minimum 313 days, and then returns to maximum in 207 days, to remain again at that brightness for twenty-five years.

Miss CLERKE points out, however, (*The Observatory*, March, 1904,) from the data given, that the mass of the system must be 188,000 times that of the Sun. She thinks, therefore, that Dr. LUDENDORFF's theory, as it stands, is untenable.

His Excellency the United States Ambassador attended the annual meeting of the Royal Astronomical Society yesterday to receive the gold medal which the council have awarded to Professor GEORGE E. HALE, of the Yerkes Observatory. In his presidential address Professor H. H. TURNER recounted the splendid achievements of Professor HALE, chief of which has been his invention of the spectroheliograph, "by which photographs are now made of all the prominences visible round the entire circumference of the Sun, with a single exposure, and by which faculæ are clearly shown even in the brightest portion of the Sun's disc." The Sun being the only star we can observe in detail, Professor HALE's method enables the astronomer to get over the difficulty of the excessive brightness of the solar orb and photograph the whole surface. In making the presentation, Dr. TURNER referred to the eminent services which American men of science have rendered to astronomy.

Acknowledging the gift of the medal on behalf of Professor HALE, who was unable to be present, Mr. CHOATE observed that this award was the greatest honor which an astronomer could receive. He was gratified to see how highly the work of American observers was esteemed, and to remember that only three years ago this medal was bestowed on Professor PICKERING, of Harvard. Our astronomers, he added, have rare facilities. Heaven smiles upon them. With three hundred clear days and nights in the year—which I am afraid you cannot have here in London—[laughter]—with splendid observatories provided and equipped with public and private munificence, it would be strange if they did not do well. This gift will add further stimulus to Professor HALE, and to give stimulus and nerve to such a man is to achieve the highest purpose of such an award. [Loud cheers.]—*London Daily Telegraph, Feb. 15th.*

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF
DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE
PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, ON
SATURDAY, NOVEMBER 28, 1903, AT 2 P.M.

President VON GELDERN presided. A quorum was present.

The purpose of the meeting being the Fifth Award of the Bruce Gold Medal, the letters received from the Directors of the six nominating Observatories were submitted by the Secretary. After a careful consideration of the recommendations contained in these letters, the selection of the Medalist was made by ballot, and the following certificate of bestowal was signed by all Directors present:—

SAN FRANCISCO, November 28, 1903.

FIFTH AWARD OF THE BRUCE MEDAL.

We, the undersigned Directors of the Astronomical Society of the Pacific, hereby certify, that, in accordance with the Statutes for the bestowal of the Bruce Medal, a special meeting of the Board of Directors was held this day, at two o'clock P.M., for the purpose of awarding the medal for the year 1904; and that, the provisions of the Statutes relating to its bestowal having been complied with, the medal was awarded to—

WILLIAM HUGGINS,

for Distinguished Services to Astronomy, by the consenting votes of eleven Directors.

Signed: R. G. AIKEN,* CHAS. BURCKHALTER, W. W. CAMPBELL,*
WM. H. CROCKER,* CHAS. S. CUSHING,* OTTO VON GELDERN,
A. O. LEUSCHNER, E. J. MOLERA,* WM. M. PIERSON,* S. D.
TOWNLEY,* F. R. ZIEL.

Adjourned.

(* By proxy.)

In answer to a letter addressed to Sir WILLIAM HUGGINS, notifying him of the action taken by the Directors, the following letter of acceptance was received:—

LONDON, 15 January, 1904.

DEAR SIR: I beg to acknowledge the receipt of your letter of the 1st inst., informing me of the high honour which the Board of Directors of the Astronomical Society of the Pacific have conferred upon me by the award to me of the "Bruce Gold Medal" for the year 1904. In accordance with the Statute to which you call my attention, I beg herewith to express formally my grateful acceptance of this mark of high distinction bestowed upon me by your Society; I shall always look upon the medal as among the most prized of my possessions.

I have the honour to remain,

Yours very faithfully,

WILLIAM HUGGINS.

To F. R. ZIEL, Esq.,

Secretary Astronomical Society of the Pacific.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 26, 1904, AT 7:30 P.M.

President VON GELDERN presided. A quorum was present. The minutes of the last meeting were read and approved. The following members were duly elected:—

LIST OF MEMBERS ELECTED MARCH 26, 1904.

OAKLAND FREE PUBLIC LIBRARY....Oakland, Cal.

Mr. E. J. DE SABLE, JR.*..... 615, Rialto Building, S. F., Cal.

Dr. A. S. TUCHLER..... { N. W. cor. Van Ness Ave. and
Turk St., S. F., Cal.

REPORT OF THE LIBRARY COMMITTEE.

The Library Committee presented its report, as follows, and the report was accepted and filed:—

SAN FRANCISCO, CAL., March 26, 1904.

To the Board of Directors of the Astronomical Society of the Pacific:

We, the undersigned Committee of the Society's Library, report as follows:

Since the last annual report the manuscript catalogue, authorized by the Board of Directors, has been completed and will be published in the August number of the *Publications*.

By binding, purchase, and gift the number of volumes on the accessions-book has been increased during the past year from 1,258 to 1,344.

The expenditures from the Alexander Montgomery Library Fund may be found in the Treasurer's report.

Respectfully submitted,

SIDNEY D. TOWNLEY, *Librarian*.

ROSE O'HALLORAN.

The Finance Committee reported that, pursuant to the Resolution adopted March 28, 1903, authorizing the investment of the funds of the Society in bonds, they had bought eight bonds, at a total cost of \$8,059.44;—an itemized account of the cost and distribution of these bonds among the several funds being contained in the Treasurer's Report.

Adjourned.

* A star denotes Life Membership.

MINUTES OF THE SIXTEENTH ANNUAL MEETING OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE
ROOMS OF THE SOCIETY, MARCH 26, 1904, AT 8 P.M.

The meeting was called to order by President VON GELDERN. A quorum was present. The minutes of the last meeting were approved. The Secretary read the names of new members duly elected at the Directors' meeting.

The following papers were presented:—

1. Address of the retiring President of the Society, by OTTO VON GELDERN.
2. Reports of Committees: on Nominations; on the Comet Medal; on the Library on Auditing; and Annual Report of the Treasurer.
3. Photographs of Comet Borrelly, by SEB. ALBRECHT.
4. Variable Star Notes, by Miss O'HALLORAN.
5. A Few Details of the Twelve-Year Sun Spot Cycle, by Miss O'HALLORAN.
6. Planetary Phenomena for May and June, 1904, by M. MCNEILL.
7. The Supporting and Counterweighting of the Principal Axes of Large Telescopes, by C. D. PERRINE.

The Committee on Nominations reported a list of names proposed for election as Directors, as follows: Messrs. R. G. AITKEN, CHAS. BURCKHALTER, W. W. CAMPBELL, WM. H. CROCKER, CHAS. S. CUSHING, GEO. C. EDWARDS, A. O. LEUSCHNER, GEO. C. PARDEE, WM. M. PIERSON, S. D. TOWNLEY, F. R. ZIEL.

For Committee on Publication: Messrs. R. G. AITKEN (Chairman), FRANK SCHLESINGER, S. D. TOWNLEY.

Messrs. SCHIRMAN and ATKINS were appointed as tellers. The polls were open from 8:15 to 9 P.M., and the persons above named were duly elected to serve for the ensuing year.

REPORT OF THE COMMITTEE ON THE DONOHUE COMET-MEDAL.

Submitted March 26, 1904.

This reports relates to the Calendar year 1903. The Comets of 1903 have been:—

Comet *a* (unexpected comet), discovered by M. GIACOBINI, at Nice, on January 15th.

Comet *b* (unexpected comet), discovered by Mr. JOHN GRIGG, at Thames, N. Z., on April 16th.

Comet *c* (unexpected comet), discovered by M. BORRELLY, at Marseilles, France, on June 21st.

Comet *d* (Brooks's periodic comet, 1889 V, 1896 VI), observed on its return by R. G. AITKEN, at the Lick Observatory, August 18th.

In accordance with the Statutes. Donohue Comet-Medals have been awarded to the discoverers of Comets *a*, *b*, and *c*.

W. W. CAMPBELL,
CHAS. BURCKHALTER,
WM. M. PIERSON,

Committee on the Donohue Comet-Medal.

The Treasurer submitted his Annual Report as follows:—

**ANNUAL STATEMENT OF THE RECEIPTS AND EXPENDITURES OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE
FISCAL YEAR ENDING MARCH 26, 1904.**

GENERAL FUND.

Receipts.

1903, March 29th. Cash Balance		\$5,414 68
Received from dues for 1903 and previous years	\$280 97	
" " " 1904	571 40	
" " Life membership fee	50 00	\$902 37
" " sale of Publications	54 00	
" " Life Membership Fund (interest)	56 67	
" " John Dolbeer Fund (interest)	107 74	1,120 78
		<hr/>
		\$6,535 46
Less transfer to John Dolbeer Fund	\$5,000 00	
" " " Life Membership Fund	50 00	5,050 00
		<hr/>

\$1,485 46

Expenditures.

For Publications: printing Nos. 89 to 93 of Vol. XV.	\$530 70	
" " No. 94 of Vol. XVI.	134 50	
illustrations	23 25	\$688 45
Stationery and printing	87 95	
Postages	65 32	
Rent	180 00	
Salary Secretary-Treasurer	180 00	
Expressages	11 15	
Telephone and Telegrams	2 25	
Janitor	4 00	
Gas	1 55	
Insurance premiums	24 00	
Lantern at lecture	8 50	
Engrossing diplomas	9 00	
Taxes	2 70	
Bank Exchanges	10	
Rent safe deposit box	5 00	1,269 97
		<hr/>
1904, March 26th. Cash Balance		\$ 215 49

LIFE MEMBERSHIP FUND.

1903, March 29th. Cash Balance	\$1,703 95
Received from General Fund	50 00
Interest for 1903	56 67
	<hr/>
	\$1,810 62
Less transfer to General Fund (interest)	56 67
	<hr/>
1904, March 26th. Cash Balance	\$1,753 95

ALEXANDER MONTGOMERY LIBRARY FUND.

1905, March 26th. Cash Balance	\$755 14
Interest for 1905	46 33
	<hr/> \$793 47
Less expenditures:	
<i>Astronomical Journal</i> , 1 Nos.	\$ 1 30
<i>Astronomische Nachrichten</i> , Vols. II and III	9 50
Hicks-Junt Co., binding	26 12
<i>Harvard & Yale</i> , Vol. III	75
<i>Popular Astronomy</i> subscription, Nos. 111 to 120	2 98
<i>Astronomical Journal</i> , Vols. 20, 21, 22	4 73
<i>Astronomische Nachrichten</i> , Vols. 159, 160, 161	7 38
Checking card catalogue and card index	13 30
Preparing Manuscript Catalogue of bound books	21 30
	<hr/> 147 56
1904, March 26th. Cash Balance	<hr/> \$745 61

DODDHOE COMET-MEDAL FUND.

1905, March 26th. Cash Balance	\$705 58
Interest for 1905	23 20
	<hr/> \$728 78
Less engraving medals Nos. 43, 44, 45, and postage	4 53
1904, March 26th. Cash Balance	<hr/> \$724 35

BRUCE MEDAL FUND.

1905, March 26th. Cash Balance	\$2,545 79
Interest for 1905	79 64
	<hr/> \$2,625 43
Less remittance to A. Dreyer, Paris (5th award)	101 95
1904, March 26th. Cash Balance	<hr/> \$2,525 48

JOHN DOLBEER FUND

1905, March 26th. Payment by General Fund	\$5,000 00
Interest for 1905	107 74
	<hr/> \$5,107 74
Less transfer to General Fund (interest)	107 74
1904, March 26th. Cash Balance	<hr/> \$5,000 00

FUNDS.

Balances as follows:

General Fund:

with Donohoe-Kelly Banking Co. \$215 49

Life Membership Fund:

with San Francisco Savings Union \$ 303 95
 " German Savings and Loan Society 250 00
 " Hibernia Savings and Loan Society 200 00

South Pacific Coast Railway Co., 1st Mortgage 4% guaranteed
 (by S. P. Co.) \$1,000 Gold Bond, No. 3,406 1,000 00 1,753 95
 (Principal due July 1, 1937; interest Jan. 1 and July 1.)

Alexander Montgomery Library Fund:

with San Francisco Savings Union \$ 165 89
 " German Savings and Loan Society 138 06
 " Hibernia Savings and Loan Society 71 66

Oakland Transit Consolidated, 1st consolidated Mortgage 5%
 \$1,000 Gold Bond, No. 4,328 1,040 00 1,415 61
 (Principal due July 1, 1932; interest Jan. 1 and July 1.)

Donohoe Comet-Medal Fund:

with San Francisco Savings Union \$ 224 64
 " German Savings and Loan Society 245 26
 " Hibernia Savings and Loan Society 254 45 724 35

Bruce Medal Fund:

with San Francisco Savings Union \$ 215 49
 " Security Savings Bank 159 11
 " German Savings and Loan Society 162 16

Bay Counties Power Co., 1st consolidated Mortgage 5% \$1,000
 Sinking Fund Gold Bond, No. 1,636 1,012 50
 (Principal due Sept. 1, 1930; interest Mar. 1 and Sept. 1.)

The Edison Electric Co., Los Angeles, 1st and Refunding Mortgage 5% \$1,000 Gold Bond, No. 168 977 22 2,526 48
 (Principal due Sept. 1, 1922; interest Mar. 1 and Sept. 1.)

John Dolbeer Fund:

with Union Trust Co. 570 28
 " Mutual Savings Bank 400 00

South Pacific Coast Railway Co., 1st Mortgage 4% guaranteed
 (by S. P. Co.) \$1,000 Gold Bond, No. 3,407 1,000 00
 (Principal due July 1, 1937; interest Jan. 1 and July 1.)

Oakland Transit Consolidated, 1st consolidated Mortgage 5%
 \$1,000 Gold Bond, No. 4,329 1,040 00
 (Principal due July 1, 1932; interest Jan. 1 and July 1.)

Bay Counties Power Co., 1st consolidated Mortgage 5% \$1,000
 Sinking Fund Gold Bond, No. 1,637 1,012 50
 (Principal due Sept. 1, 1930; interest Mar. 1 and Sept. 1.)

The Edison Electric Co., Los Angeles, 1st and Refunding Mortgage 5% \$1,000 Gold Bond, No. 169 977 22 5,000 00
 (Principal due Sept. 1, 1922; interest Mar. 1 and Sept. 1.)

\$11,635 88

SAN FRANCISCO, March 26, 1904.

F. R. ZIEL, *Treasurer.*

Examined and found correct.

CHAS. S. CUSHING, { *Auditing Committee.*
 DANIEL SUTER,

The report was, on motion, accepted and filed.

The Committee appointed to audit the Treasurer's accounts reported as follows, and the report was, on motion, accepted and adopted:—

SAN FRANCISCO, CAL., March 26, 1904.

To the President and Members of the Astronomical Society of the Pacific:

GENTLEMEN—Your committee appointed to audit the accounts of the Treasurer for the fiscal year ending March 26, 1904, has made a careful examination, and found the same to be correct.

Respectfully submitted,

CHAS. S. CUSHING, { *Auditing Committee.*
DANIEL SUTER, }

The President then read his annual address awarding the Bruce Medal for the year 1904, to Sir WILLIAM HUGGINS for distinguished services to Astronomy.

Dr. TOWNLEY gave an account of the work being done at the Latitude Observatory at Ukiah.

The following resolution was, on motion, adopted:—

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by said Board during the past fiscal year, are here now, by this Society, approved and confirmed.

Adjourned.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY,
MARCH 26, 1904, AT 9:30 P.M.

The new Board of Directors was called to order by Mr. LEUSCHNER. A quorum was present. The minutes of the last meeting were approved.

The first business in hand being the election of officers for the ensuing year, the following officers, having received a majority of the votes cast, were duly elected:—

President: Mr. GEO. C. EDWARDS.

First Vice-President: Mr. S. D. TOWNLEY.

Second Vice-President: Mr. CHAS. S. CUSHING.

Third Vice-President: Mr. A. O. LEUSCHNER.

Secretaries: Messrs. R. G. AITKEN and F. R. ZIEL.

Treasurer: Mr. F. R. ZIEL.

The President was authorized to appoint the standing committees of the Society, and made the following selections:—

Committee on the Comet-Medal: Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

Library Committee: Messrs. TOWNLEY, BABCOCK, Miss O'HALLORAN. Mr. TOWNLEY was appointed Librarian.

Finance Committee: Messrs. CUSHING (*Chairman*), PIERSON, LEUSCHNER.

The Committee on Publication is composed of: Messrs. R. G. AITKEN (*Chairman*), FRANK SCHLESINGER, S. D. TOWNLEY.

The Board of Directors is composed of: Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, EDWARDS, LEUSCHNER, PARDEE, PIERSON, TOWNLEY, and ZIEL.

The following resolutions were, upon motion, duly adopted:—

Resolved, That the income from the John Dolbeer Fund be in future devoted to specific purposes, and that it shall become available only through a resolution duly adopted at a regular or special meeting of the Board of Directors; provided, however, that the income for the fiscal year 1904-1905 be devoted to the *Publications* of the Society, and that an acknowledgment to the Dolbeer Fund be printed in the *Publications*.

Resolved, That the amount to be withdrawn from the General Fund or publication purposes during the fiscal year 1904-1905 shall not exceed the sum of \$500.

Resolved, That the names of the members of the Committee on Publication be printed on the inside of the front page of the cover of the *Publications*.

Resolved, That the new catalogue of the bound books be published as the August number of Vol. XVI of the *Publications*.

Resolved, That the name of the Société Belge d'Astronomie, of Brussels, Belgium, be placed on the list of corresponding institutions.

Resolved, That the opening of the safe deposit box of the Society with the California Safe Deposit and Trust Co. be intrusted to the following committee of two members of the Board of Directors, jointly, namely, F. R. ZIEL (Secretary), and CHAS. S. CUSHING (Chairman of the Finance Committee), and that the California Safe Deposit and Trust Co. shall be officially notified of any change in the names of the Committee, in writing, by the President and Secretary, under the seal of the Society.

Adjourned.

132 *Publications of the Astronomical Society, &c.*

OFFICERS OF THE SOCIETY.

Mr. GEO. C. EDWARDS	<i>President</i>
Mr. S. D. TOWNLEY	<i>First Vice-President</i>
Mr. CHAS. S. CUSHING	<i>Second Vice-President</i>
Mr. A. O. LEUSCHNER	<i>Third Vice-President</i>
Mr. R. G. AITKEN)	<i>Secretaries</i>
Mr. F. R. ZIEL)	
Mr. F. R. ZIEL	<i>Treasurer</i>
<i>Board of Directors</i> —Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, EDWARDS, LEUSCHNER, PARDES, PIERSON, TOWNLEY, ZIEL.	
<i>Finance Committee</i> —Messrs. CUSHING, PIERSON, LEUSCHNER.	
<i>Committee on Publication</i> —Messrs. AITKEN, SCHLESINGER, TOWNLEY.	
<i>Library Committee</i> —Messrs. TOWNLEY, BABCOCK, Miss O'HALLORAN.	
<i>Committee on the Comet-Medal</i> —Messrs. CAMPBELL (<i>ex-officio</i>), PIERSON, BURCKHALTER.	

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book-keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
(February, April, June, August, October, December.)





CONTENTS.

The Students' Observatory at Berkeley	<i>Frontispiece</i>
von Geldern, Otto. —Address of the Retiring President of the Society in Awarding the Bruce Medal to SIR WILLIAM HUGGINS	PAGE 49
Albrecht, S. —Photographs of BORRELLY'S Comet	62
DEDICATION OF THE STUDENTS' OBSERVATORY AT BERKELEY:—	
Campbell, W. W. —Introductory Remarks	65
Leuschner, A. O. —History and Aims of the Students' Observatory	68
Crawford, R. T. —The Constant of Refraction	78
Newkirk, B. L. —The Watson Asteroids	85
Gilliban, A. F. —The Photographic Equatorial of the Stu- dents' Observatory.	89
O'Halloran, Rose. —A Few Details of the Twelve-Year Sun- Spot Cycle	93
Perrine, C. D. —The Supporting and Counterweighting of the Principal Axes of Large Telescopes	97
McNeill, M. —Planetary Phenomena for May and June, 1904 . .	99
O'Halloran, Rose. —Variable Stars.	101
(Forty-Sixth) Award of the Donohoe Comet-Medal	103
Reports of Observatories	104
Notices from the Lick Observatory	117
General Notes	120
Minutes of Meeting of Board of Directors, November 28, 1903 .	124
Minutes of Meeting of Board of Directors, March 26, 1904 . . .	125
Minutes of Annual Meeting of the Society, March 26, 1904 . . .	126
Minutes of Meeting of Board of Directors, March 26, 1904 . . .	131
Officers of the Society.	132

PUBLICATIONS
OF THE
ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI.
NUMBER 96.
1904.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY.

1904.

[Entered at Post Office at San Francisco, Cal., as second-class mail matter.]

COMMITTEE ON PUBLICATION.

ROBERT G. AITKEN, Mt. Hamilton, Cal.

FRANK SCHLESINGER, Williams Bay, Wis.

SIDNEY D. TOWNLEY, Ukiah, Cal.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, JUNE 10, 1904. No. 96.

A BRIEF REVIEW OF RECENT PROGRESS IN
SOLAR PHYSICS.

BY HEBER D. CURTIS.

ANNALES L'OBSERVATOIRE D'ASTRONOMIE PHYSIQUE DE PARIS,
SIS PARC À MEUDON. Tome I, 1896.

— ATLAS DES PHOTOGRAPHIES SOLAIRES. Tome I, 1903.

THE RUMFORD SPECTROHELIOGRAPH OF THE YERKES OBSERVA-
TORY. *Publications of the Yerkes Observatory*, Vol. III,
Part I, 1903.

ANNALS OF THE ASTROPHYSICAL OBSERVATORY OF THE SMITH-
SONIAN INSTITUTION. Vol. I, 1900.

INTENSITÉ DE LA RADIATION SOLAIRE A DIFFÉRENTES ALTI-
TUDES. RECHERCHES FAITES A TÉNÉRIFFE 1895 ET
1896 PAR KNUT ÅNGSTRÖM. *Nova Acta Reg. Sec. Sci-*
ent. Upsaliensis XX, fasc. I, 1901.

REPORT OF THE COMMITTEE ON SOUTHERN AND SOLAR OBSER-
VATORIES. Published by the Carnegie Institution, 1903.

Although the researches covered by these superbly printed volumes in some cases reach back twenty years or more, the recent publication of the results secured may warrant a brief résumé of the progress recorded in these epoch-marking monographs.

It is a far cry from the first daguerreotype of the Sun, made in 1845 by FIZEAU and FOUCAULT, to the great plates of the Meudon folio, photographed for the most part on a scale of 0^m.30 to the Sun's diameter and enlarged to a solar diameter of 1^m.20. In the volume of the Annals the plates have been

enlarged to a solar diameter of $0^m.894$; and as the plates given in the Atlas cover the same general ground and the letter-press is practically a reprint of that in the Annals, it is possible that many will consider the partial duplication of work in the Atlas an expenditure not warranted by the additional results made accessible. There can be no question, however, as to the beauty of this fine folio, or the excellence of its great prints, nearly eighteen by twenty-one inches in size. The photographs were secured with a telescope and lens by PRAZMOWSKI, $0^m.135$ (5.3 in.) in aperture, described by M. JANSSEN as of rare optical perfection. In the taking of the plates of this series as large as possible a measure of monochromatism was sought for. This result has been achieved by careful choice and figuring of the glass of the lens to secure a sharply defined maximum of photographic effect near G. In like manner the collodion plates employed were composed from formulæ found by experiment to give a similar maximum, quite limited in extent, at the same region of the spectrum, and great pains were taken and special precautions employed in the manufacture of the collodion emulsion to secure plates of exceeding fineness of grain. The negatives were generally on a scale of $0^m.30$, though sometimes $0^m.50$, or even $0^m.70$, was employed. Some of the plates show a sharpness and fineness of detail which it would be difficult to improve. Plates I, III, XIX, and XXI are unusually good. The average size of the granulations is from one to two seconds of arc, though not infrequently details can be seen measuring not more than one fourth to one third of a second.

One of the more important of M. JANSSEN's results, aside from the granular structure itself and the relegation of "willow-leaf" to the limbo of discarded theory, is the fact that the granular structure generally persists right up to the visually much brighter edge of spots and through the striæ of spot penumbraë. Moreover, there seems to be no essential difference in the granulations at the poles as compared with the central regions. Many of the plates show quite plainly the so-called *réseau photosphérique*, or network, in which these granulations are frequently arranged, generally of a roughly polygonal form. The nature of the granulations seems to be entirely analogous to roughly spherical clouds floating in a

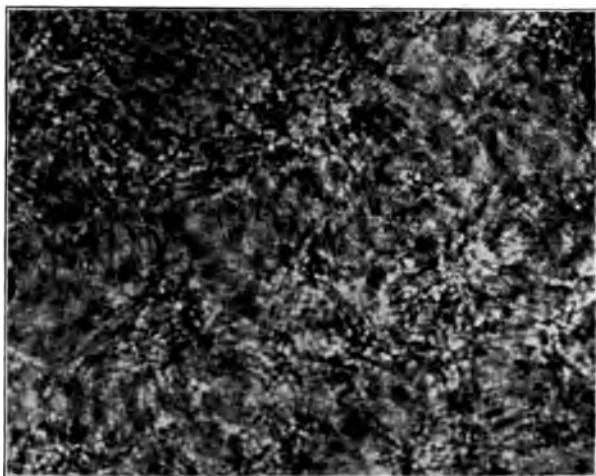


FIGURE 1.—A portion of Plate IX, *Meudon Atlas des Photographies Solaires*.

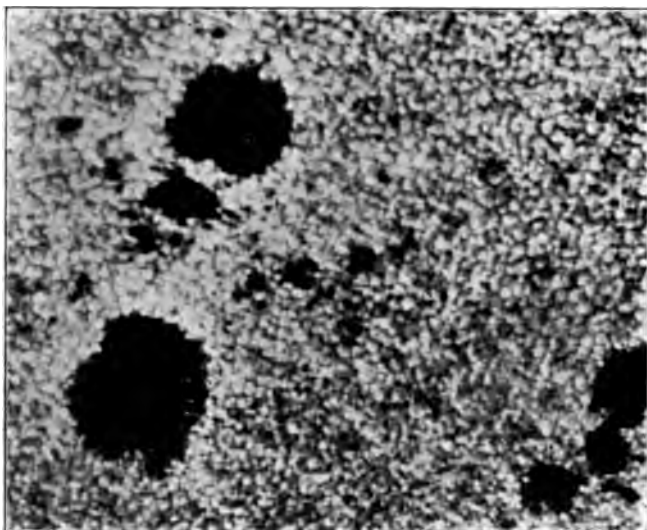


FIGURE 2.—A portion of Plate XIX, *Meudon Atlas des Photographies Solaires*.

less luminous medium. JANSSEN estimates that were the entire solar surface of the same radiating power as the granulations the intensity of the solar radiation would be quintupled. The *réseau* JANSSEN holds to be a result of different stages in the development of the granulations. The solar surface is composed of sections relatively quiescent while adjacent regions are in a condition of great activity. This can be seen easily in Figure 1, which is a small section of Plate IX of the Atlas, on nearly the same scale. Where the regions of quiescence obtain the granulations are sharp and well-defined. In adjacent regions of greater activity the separate grains merge into a more or less confused whole, the sum total giving the effect of a network or pattern. Sometimes the figures of the "pattern" are much smaller than at others, and at times they may be a minute of arc or more in diameter. In Figure 2, taken from Plate XXI, the network is wanting, and the granulations are very well defined and show an approximately spherical form.

M. JANSSEN's theory of the *réseau photosphérique* has been given here, although it has more than once been called in question. It has been pointed out that this phenomenon may instead be produced in our own atmosphere, or even within the telescope itself. It has often been asked why two photographs could not be taken very close together to settle this objection once for all (*cf.*, among others, LANGLEY, *Amer. Jour.*, XV., pp. 297 ff.). This may be more difficult than it seems, as the conditions of good seeing necessary for a perfect plate are generally very brief. But it would seem to be possible to take two such plates, and that even if one was of inferior quality, definite evidence as to the true solar character of the *réseau* might be secured. No more recent statement of this hypothesis is given in these volumes than M. JANSSEN's original announcement of discovery made in 1877 and reprinted in both the Annals and the Atlas. In view of Dr. HALE's experiences with brief intervals of poor seeing in his spectroheliographic work and Professor LANGLEY's experiments on improved images secured by mechanical stirring of the air in the telescope-tube or immediately in front of the lens, the solar character of the *réseau* would seem to be open to doubt till absolutely confirmed by consecutive exposures at brief intervals.

The Meudon photographs are to a considerable extent monochromatic, as they are taken with light from a small and sharply limited portion of the spectrum. They represent perhaps the highest present development in the study of the solar surface from methods purely photographic in their nature. In the researches of Dr. HALE and his assistant, Mr. ELLERMAN, we have this principle of monochromatism pushed to its logical conclusion, and with the aid of the spectroheliograph it is now possible to take photographs of the solar surface in light which is purely monochromatic. The principle of the instrument, though well known, will bear restatement in this résumé; it is most simple in theory for all its ingenuity, but must require a very high degree of what may perhaps best be termed instrumental ability for the securing of the excellent photographs shown in the fine plates of this volume. A long, curved slit admits light to a powerful spectroscope, preferably a combination of grating and prisms to secure a sufficiently high dispersion and freedom from diffused light. From the resulting spectrum a given line is segregated by means of a second slit, behind which is placed the photographic plate. This arrangement would then give a photograph of a narrow line on the solar surface in light of the chosen wave-length. To secure the photograph of an area or of the entire solar disk the Sun's image must be made to travel across the first slit, while the photographic plate is made to travel past the second slit in synchronism with the movement of the solar image. This gives the entire area in light which is purely monochromatic and furnishes a powerful method of research, of which it is not at all too much to say that no more marked advance in the study of the Sun's surface has ever been made. Moreover, as successive photographs can be taken in light of the same substance at different wave-lengths, or even at different portions of a broad band, astrophysics has gained a method of which it may well be predicted that not a little light will eventually be thrown on more general physical and chemical problems, gained from the behavior of matter in a monster laboratory whose conditions we can never hope to duplicate by methods purely terrestrial.

The volume gives a description of the new Rumford spectroheliograph, much more powerful than Dr. HALE's previous

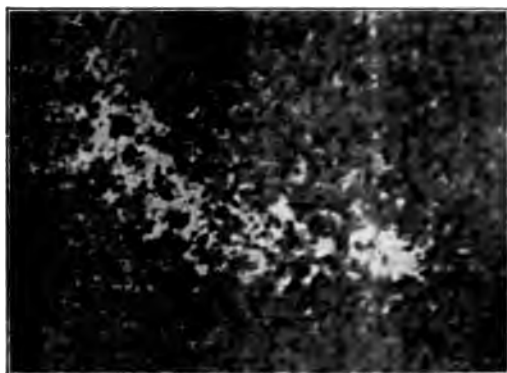


FIGURE 3.—Calcium Flocculi, photographed with light from the lower K_1 level.

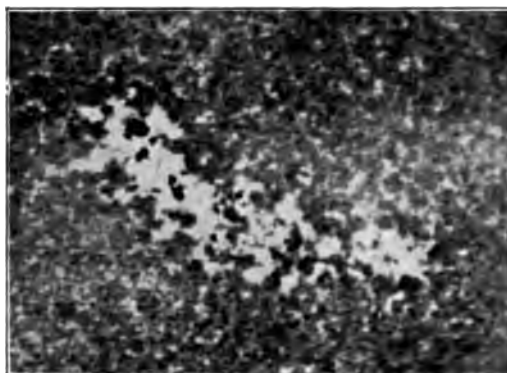


FIGURE 4.—The same Flocculi photographed with light from the K_2 level.

(Figures 3 and 4 are from *Publ. Yerkes Obs.*, Vol. III., Part I., Plate V.)

instruments, and a statement of the results thus far secured. By this method Dr. HALE has taken numerous photographs by the light from different portions of the H and K bands, the calcium line at $\lambda 4226$ and $H\beta$. Attempts have also been made to use some of the stronger iron lines, but for this latter purpose it is found that a more powerful equipment will be needed.

In general the calcium "focculi" photographed with light from H and K are of dimensions about the same as those of the granulations on the Meudon photographs, and are probably different views of the same formation. But the greatest interest attaches to the photographs made in light of different wave-lengths of the same substance. Marked differences are found, according as the calcium focculi are photographed in light of the H and K bands at their broadest, called by the authors H_1 and K_1 , or in their narrowed state as they appear in the lower levels of the chromosphere (H_2 , K_2). Eventually it is hoped to be able to secure impressions with these lines in their still narrower state as they appear in the upper chromosphere and prominences (H_3 , K_3). It will be noted in Figures 3 and 4 that the photograph from light at the K_2 level shows the focculi spread over a much greater area than the plates taken at the lower levels of K_1 . Undoubtedly these differences are due to the fact that these photographs represent different *levels* of the calcium vapor in the focculi. We get, then, in effect, several *cross-sections* of a focculus, and in general the evidence points to a "structure composed of expanding columns of calcium vapor." Considerable differences have likewise been found between photographs made with H and K light, as compared with those taken from the calcium line at $\lambda 4226.9$ — differences which the authors prefer to leave for tests with more powerful apparatus to explain. *Dark* calcium focculi have also been photographed. The photographs taken with light from the hydrogen line at $H\beta$ show that the focculi due to this element are in general dark, though bright in exceptional cases. The hope is expressed that with a larger solar image and higher dispersion it may later be possible to photograph the hydrogen focculi at different levels as has already been done for calcium.

It would be futile to try to estimate the importance of this

advance in methods for the study of all solar eruptive phenomena. It is not improbable that much evidence will eventually be secured on theories of dissociation and chemical combination in fields but remotely connected with astronomical science. The essentials for future progress in photoheliographic work are a larger solar image, greater dispersion in the instrument, and, most important, good day conditions of "seeing," requirements which are now being secured.

No outline of recent progress in solar physics would be complete without reference to the bolometric work of the Astrophysical Observatory of the Smithsonian Institution. As in the case of some of the other volumes noted in this summary, inasmuch as the work covered dates back over twenty years to its inception by Professor LANGLEY, it might be more fitting to regard it as a recently erected landmark of past progress. Under Professor LANGLEY at Allegheny and the Smithsonian Institution, and later in the skilled hands of ABBOT, the original bolometer has been improved with the use of prisms of rock-salt, constant-temperature control, almost automatic photographic registration of results, and galvanometers of the most extreme sensitiveness, till the infra-red spectrum has been mapped from λ 7600, the limit of the visual spectrum, to λ 53000, a stretch of previously unknown spectrographic territory eight times as large as all that had been known before. Aside from its purely theoretical interest, the study of this long stretch of invisible solar thermal radiation, the determination of the circumstances of its absorption by our atmosphere, and its possible variations during a sun-spot period are questions of the highest economic importance.

In this connection the observations of the solar constant made simultaneously at different altitudes on the island of Ténériffe by ÅNGSTRÖM are of interest. His work is noted here not because of any novelty in the results, for other similar investigations have been carried out, but because in the employment of the compensation pyrheliometer devised by him we have what will probably prove to be a very distinct advance over former instrumental means for determining the solar constant. Though described in the Upsala publications and also in the *Astrophysical Journal* (Vol. IX, pp. 399 ff.), a brief outline of its principle may not be out of place. Two

precisely similar blackened strips of platinum are connected with the terminals of a thermopile. One of these strips is exposed to the rays of the Sun, the other is covered by a screen. The rise in temperature in the exposed strip is compensated in the screened strip, and at the same time measured, by electrically heating it the same amount, the thermopile, in connection with the employment of delicate electrical measuring devices, forming a very sensitive thermal balance. As the strip which receives the radiation is under precisely the same conditions as the strip which measures the amount of the radiation, many troublesome corrections are obviated and the speed of the determinations is very much higher than in other forms, a few seconds instead of three to five minutes or longer.

Plans for the future are frequently the best norm of past progress. The Report of the Committee of the Carnegie Institution on Southern and Solar Observations is a most clear, definite, and straightforward presentation of the most pressing present-day problems in astronomy and astrophysics. The report makes very interesting reading, and it gives indirectly, through its plans for future work, a clear conspectus of the present boundaries in these sciences. Astronomers cannot fail to feel that the committee has wisely and without bias chosen the most fruitful lines for future research in astronomy and astrophysics; this the more, as the report is in many ways a summation of the opinions of the leaders, both American and foreign, in these sciences. An appendix is devoted to these opinions in the form of letters written to the committee, and they show on the whole great unanimity.

The recommendations for the solar observatory contemplate a main station and two substations. At the main station, aside from researches on stars and nebulae, the solar work will be limited to two or three definite lines of research.

(1) "Frequent measurement of the solar constant, together with studies on the absorption of the solar atmosphere and the radiation of different portions of the Sun's image, such as spots, faculae, and prominences. The principal instruments needed for this research are a 16-inch cœlostast and a large spectrobolometer for the solar constant work, and a 30-inch cœlostast with concave mirror of about 200 feet focal length,

for providing a solar image suitable for detailed radiation work."

(2) "Systematic observations, with large spectrographs and spectroheliographs, on such problems as the solar rotation, the structure and nature of sun-spots, faculæ, etc., and other problems related to the solar constitution. For this work there will be required two 30-inch cœlostats, used in conjunction with objectives and mirrors ranging in focal length from 64 feet to 200 feet; two large plane-grating spectroscopes, having focal lengths of about 21 feet and 42 feet respectively, provided with auxiliary for work with the spark and arc; a three prism spectroheliograph of about 10 inches aperture, and a three-prism spectroheliograph of 8 inches aperture and about 33 feet focal length."

Great care has been taken that no mistake should be made in the selection of the site for this important station, and in an appendix is given the full and interesting report of Professor W. J. HUSSEY's thorough search for the best conditions of seeing obtainable at several elevated sites in Southern California and Arizona. In the use of a large solar image, which is so essential to further progress in spectroheliographic work, good day conditions are absolutely required. Professor HUSSEY's investigations show that Mt. Wilson, near Pasadena, is possessed of unusually favorable conditions of seeing, both by day and by night. Professor HUSSEY's further report on his search for suitable sites in Australia will be awaited with great interest.

It is gratifying to be able to add, from press reports, that Dr. HALE has been given a preliminary grant of \$10,000 by the Carnegie Institution, and that he, with two assistants, is now installing the Snow horizontal telescope of the Yerkes Observatory and other apparatus at the summit of Mt. Wilson.

The two projected substations are to be devoted primarily to the determination of the solar constant at different altitudes, and its possible variation, together with researches on atmospheric absorption. The instruments needed would be the same at each station, a 16-inch cœlostat and spectrobolometer for the solar-constant work. One station will be located on as high a mountain as will be found practicable and the other at *its* base. Mt. Whitney has been suggested as a very favorable

site, but this point will be investigated further before any definite recommendation is made as to the location of the substations. It is purposed to continue the work at the main station throughout at least one sun-spot period, and for two or three summers at the two substations.

With the foresight and thoroughness with which the committee has made its plans and preliminary investigations as an earnest of the wise future administration of its trust, with the powerful equipment for which these recommendations call, and with plans founded on the notable advances of the past twenty years, astrophysicists may well hope for a decade of unparalleled progress in the field of solar physics.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter, July 5, 8 ^h 54 ^m P.M.	Last Quarter, Aug. 4, 6 ^h 3 ^m A.M.
New Moon, " 12, 9 27 P.M.	New Moon, " 11, 4 58 A.M.
First Quarter, " 19, 12 49 P.M.	First Quarter, " 17, 8 27 P.M.
Full Moon, " 27, 1 42 A.M.	Full Moon, " 25, 5 2 P.M.

The Earth is in aphelion July 4th, 5 P.M., Pacific time.

Mercury is a morning star on July 1st, too near the Sun to be seen, rising about three quarters of an hour before sunrise. It rapidly approaches the Sun, passes superior conjunction, and becomes an evening star on July 9th. By August 1st it has receded far enough from the Sun to set rather more than an hour after sunset, and this interval does not change very much until after the middle of the month. It reaches greatest east elongation on the evening of August 19th. Its apparent distance from the Sun will then be $27^{\circ} 24'$. This elongation is much greater than the average greatest elongation, since the planet passed its aphelion on August 17th, only two days before. After passing greatest elongation the planet approaches

the Sun quite rapidly, and at the end of the month it sets about half an hour after sunset. It is in close conjunction with *Mars* on the morning of July 2d, but both bodies are almost too near the Sun for observation at that time. Also, it is in conjunction with *Venus* only ten hours after passing conjunction with the Sun.

Venus is a morning star too near the Sun to be easily seen on July 1st. It comes to superior conjunction July 7th, 11 P.M., Pacific time. It then becomes an evening star, and will remain so until the following spring. Its apparent distance from the Sun increases rather slowly, and its path among the stars tends toward the south; so the interval between the setting of the Sun and of the planet does not grow very rapidly. On August 1st it is only thirteen minutes, and on August 31st about forty minutes. Notwithstanding its brightness, now at its minimum, it will not be easy to see it with the naked eye until nearly the close of August. It is in perihelion on July 23d, but its orbit is so nearly circular that the difference between greatest and least distance from the Sun is less than half a million miles.

Mars is now getting far enough away from the Sun to be seen as a morning star. On July 1st it rises about forty minutes before sunrise, on August 1st an hour and a half before, and on August 31st well over two hours before. During the two months it moves over 40° eastward and 6° southward in *Gemini*. During the middle and latter part of August it is a few degrees south of *Castor and Pollux*, α and β *Geminorum*.

Jupiter rises half an hour after midnight on July 1st, and by the end of August at a little before 9 P.M. It moves eastward in the eastern part of *Pisces* until August 20th, about 3° , and then begins to move slowly westward.

Saturn rises before 10 P.M. on July 1st, and at about 5:40 on August 30th. So it is in fair position for early-evening observation in August. It comes to opposition with the Sun on August 10th, and is then above the horizon during the entire night. During the two months it moves about 4° westward in the constellation *Capricorn*, somewhat east of α and β , the principal stars of the constellation. The rings apparently widen out a trifle from their minimum in June, on account of the Earth's motion in reference to their plane; but aside

from this temporary increase in apparent breadth, there will be a general progressive diminution until the motion of the planet brings the plane of the rings into coincidence with the Earth.

Uranus crosses the meridian shortly after 11 P.M., on July 1st, and at 7 P.M. on September 1st. So it is in fair position for evening observation. It moves a little less than 2° westward in the western part of *Sagittarius*, becoming stationary early in September. No bright star is near enough to make the planet's identification easy.

Neptune is a morning object in *Gemini*. By the end of August it rises not long after midnight.

It will be worth while to look for the annual *Perseid* meteors during the second week in August. The meteors are so scattered that we get some every year, while there is no great shower occurring at intervals of several years,—or failing to come to time in anything like its hoped for brilliancy, as happened with the *Leonids* a few years ago.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE OBSERVATORY OF THE D. O. MILLS EXPEDITION TO CHILE.

The buildings and premises occupied by the D. O. Mills Expedition to Chile are shown in the accompanying illustrations. The station, on the summit of San Cristobal, is about two miles northeast of the center of the city of Santiago, at an elevation of 2,800 feet above sea-level, the altitude of the city being 1,800 feet. The city of Santiago is shown indistinctly in the background of one of the illustrations.

The installation of the apparatus was completed last October, and photographic results accumulated rapidly during the southern summer now coming to a close. The first installment of spectrum plates has just been received at Mount Hamilton, where they will be promptly measured and reduced. A few spectroscopic binaries have been already discovered as by-products of the programme of observations.

W. W. CAMPBELL.

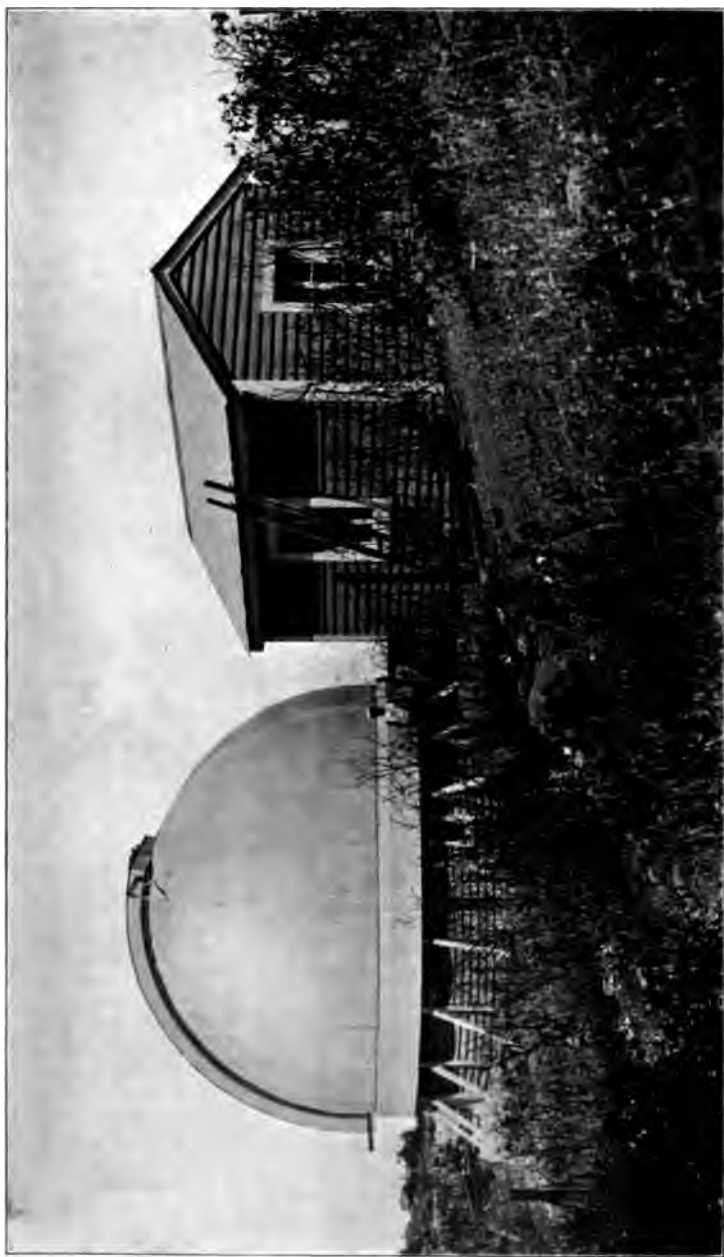
NOTE ON β 346 = *LIBRÆ* 23.

In his General Catalogue BURNHAM gives the measures of this double star from discovery in 1877 to 1888 with the note, "No material change." I have, however, secured two measures recently which seem to indicate that this pair is a binary in slow direct motion. The measures from 1877 to 1888 are rather discordant, varying between 233° and 239° , with a distance of about $1''.25$. My recent measures give an angle of $253^{\circ}.6$, with distance $1''.35$ (1904.36).

May 27, 1904.

R. G. AITKEN.

* Lick Astronomical Department of the University of California.



THE OBSERVATORY OF THE D. O. MILLS EXPEDITION.

ELEMENTS OF COMET *a* 1904 (BROOKS).

From observations on April 17th (AITKEN), May 8th (MADDRILL), and May 24th (MADDRILL), we have computed the following set of parabolic elements for this comet:—

$$\begin{array}{l} T = 1904, \text{ March } 6.9049, \text{ G. M. T.} \\ \omega = 53^{\circ} 27' 13''.8 \\ \Omega = 275 \ 46 \ 05.5 \\ i = 125 \ 07 \ 33.1 \end{array} \left. \vphantom{\begin{array}{l} T \\ \omega \\ \Omega \\ i \end{array}} \right\} \text{Mean equinox of } 1904.0.$$

$$\log q = 0.432475.$$

$$\text{Residuals } (O - C); \Delta \lambda' \cos \beta' - 1''.0; \Delta \beta' + 1''.7$$

An ephemeris based on these elements is given in *Lick Observatory Bulletin*, No. 56.

R. G. AITKEN.

J. D. MADDRILL.

May 27, 1904.

COMET *a* 1904 (BROOKS).

This comet was discovered by Dr. W. R. BROOKS on the night of April 16, 1904. The telegram announcing the discovery was received here on Sunday, April 17th, and the comet was observed with the 12-inch telescope the same evening. It was found to be a small object, fairly bright, about ninth magnitude, with a sharp nucleus of about the tenth magnitude, and a short brushy tail extending toward the south.

The preliminary orbits that have been computed for this comet show that it has a greater perihelion distance than any one of recent years except GIACOBINI'S comet (*d* 1902), the distance from the Earth at the time of discovery being nearly 2.3 astronomical units. The ephemeris computed from the elements, given on another page, indicates that the comet will remain visible in large telescopes as an evening object throughout the summer and autumn months, the brightness diminishing but slowly.

R. G. AITKEN.

May 27, 1904.

GENERAL NOTES.

In number 94 of these *Publications* we called attention to an article by Dr. HARTMANN, entitled "A Revision of Rowland's System of Wave-Lengths." Another important article bearing upon the same subject, by Professor KAYSER, appeared in the *Astrophysical Journal* for April.

The *Astrophysical Journal* for April contains also an interesting article by E. C. C. BALY, on the "Spectrum of the Aurora." Mr. BALY brings forth further evidence to show the close correspondence between the spectrum of the Aurora and that of krypton. This was previously pointed out by Professor RUNGE in the *Astrophysical Journal* for December, 1903.

A few years ago Professor BAILY, of Harvard College Observatory, made the interesting announcement that a large number of the stars contained in globular clusters were variables of small range and short period. The number of these stars found reached 509. Recently Professor PICKERING has published (*Harvard College Observatory Circular* No. 78) a list of variables found within the Nebula of *Orion*. A year or two ago Professor WOLF, of Heidelberg, discovered a number of variables in this nebula, but his discoveries remained unconfirmed until an examination of Harvard College photographic plates was made recently. Dr. WOLF's discoveries are not only confirmed, but a number of new variables have been found and Professor PICKERING has published, in the circular mentioned above, a list of 71 stars certainly variable and a second list of 35 stars suspected of variability. These stars lie within an area of 14.458 square minutes of arc, R. A. $5^{\text{h}} 27.7^{\text{m}}$ to $5^{\text{h}} 33.1^{\text{m}}$ and Dec. — $4^{\circ} 0'$ to $6^{\circ} 59'$, and about 3,000 stars were examined.

Mr. CHANDLER has given in the *Astronomical Journal*, No. 560, Ephemerides of Long Period Variables from 1903 to 1910. This includes all the stars of over one hundred days' period contained in CHANDLER's Third Catalogue, and the ephemerides have been computed from the revised elements recently published in the *Astronomical Journal*, No. 553. *M—m* and the

approximate range are given also. Observers will find this publication very serviceable in making up their observing lists.

The numbers of the *Monthly Weather Review* for 1903 contain some interesting articles on the relation between solar and terrestrial disturbances. In the January number may be found "Synchronous Changes in the Solar and Terrestrial Atmospheres," by F. H. BIGELOW; in the August number "The Periodicity of Sun-spots and the Variations of the Mean Annual Temperature of the Atmosphere," by CHARLES NORDMANN; "On the Simultaneous Variations of Sun-spots and of Terrestrial Atmospheric Temperatures," by ALFRED ANGOT; in the October number "Solar Radiations and Earth Temperatures," by C. G. KNOTT; "Studies on the Circulation of the Atmospheres of the Sun and of the Earth," by F. H. BIGELOW; in the November number "Studies on the Circulation of the Atmospheres of the Sun and the Earth, II," "Synchronism of the Variations of the Solar Prominences with the Terrestrial Barometric Pressures and the Temperatures," by F. H. BIGELOW.

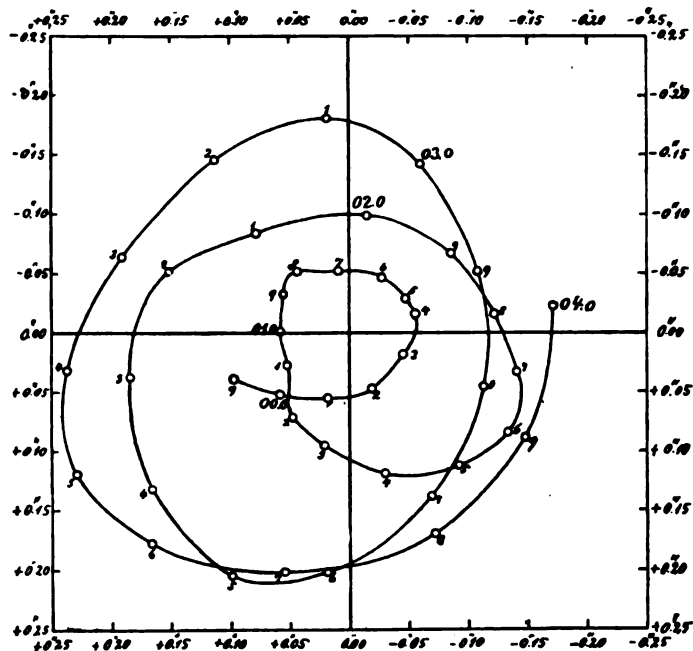
From the annual report of the work accomplished by the Central Bureau of the International Geodetic Association it appears that the number of latitude determinations made at the various stations established for the purpose of determining the variation of latitude, gives a total for 1903 of 12,552. distributed as indicated in the first column of the table given below. The total number of observations made from the time the stations were established, fall of 1899, to the beginning of 1904 is 51,725, distributed as indicated in the second column of the table.

	1903.	Total.
At Mizusawa	1,654	6,683
Tschardjni	2,014	7,454
Carloforte	3,524	13,825
Gaithersburg	1,319	8,017
Cincinnati	1,478	6,709
Ukiah	2,563	9,037

The numbers in the second column indicate something concerning the number of clear nights at the different stations.

At Mizusawa and at Carloforte there are two observers, so that probably every clear night is utilized; it would appear, then, that the Italian has twice as many clear nights as the Japanese station. The advantage of the Italian weather over that of the other stations is not so great, however, as the numbers would indicate, because there is but one observer at each of the other stations, and when such is the case it is not possible to utilize every favorable night. The relatively small number of observations obtained at Cincinnati is due to the fact that Professor PORTER, the observer, has other duties, and gives only a portion of his time to latitude work.

Provisional results for the latitude work of 1903 have been published recently by Professor ALBRECHT in the *Astronomische Nachrichten*, No. 3945. The amplitude of the polar motion has continued large throughout the year, and has probably reached a maximum. The motion of the Earth's north pole, from 1899.9 to 1904.0, referred to the mean position of the pole for 1900-1901, is represented graphically in the accompanying figure, taken from the number of the *Nachrichten* mentioned above.



It is of interest to note that Professor MILNE's suggestion, made as far back as 1893, that earthquakes may be one of the chief causes of the displacement of the Earth's poles, is yearly receiving statistical evidence for its support. (See article by M. A. DE LAPPARENT in *La Nature* for April 16th, or translation in *Literary Digest* for May 14th.) Some time ago Professor MILNE prepared a table showing the proportionality between the number of violent earthquakes and the amplitude of the polar displacement, from 1895 to 1898. More recently this table has been extended to 1902 by M. CANCANI, with the following result:—

Year.	Number of violent earthquakes.	Polar displacement.
1895	9	0".55
1896	18	0 .91
1897	44 or 47	1 .07
1898	50	1 .03
1899	27	0 .72
1900	17	0 .32
1901	22	0 .53
1902	29	0 .97

If the numbers of the second column be divided by the corresponding ones of the first column, it will be seen that a rather rough proportionality exists. The evidence is perhaps not yet sufficient to warrant the conclusion that there is here a relation of cause and effect. S. D. T.

The following notes have been taken from recent numbers of *Science*:—

Professor HENRY PERROTIN, director of the Observatory at Nice, died recently at the age of fifty-eight.

The Institute of France has received a bequest from M. JEAN DEBROUSSE, yielding an annual income of about \$6,000. A thousand dollars has been appropriated for the publication of a lunar table.

The five-foot equatorial telescope, with Newtonian and Cassegrain mirrors, and many other astronomical and optical instruments belonging to the late Dr. COMMON, are offered for sale by T. A. COMMON, 88 Wigmore Street, London, W.

At a meeting of the National Academy of Sciences held during April Sir WILLIAM HUGGINS and Professor GEORGE H. DARWIN, among others, were elected foreign associates, and the Draper gold medal was presented to Professor GEORGE E. HALE, for his researches in astrophysics.

Miss HELEN SNOW has made a gift of \$10,000 as a memorial to GEORGE W. SNOW, her father, to rebuild the horizontal telescope at Yerkes Observatory, which was injured by fire.

The Carnegie Institution has made a grant of \$1,500 in continuation of last year's grant aiding the new reduction of PIAZZI's 160,000 star observations. This work, under the direction of Dr. HERMAN S. DAVIS, Gaithersburg, Md., is now well advanced, previous assistance having also been rendered by Miss BRUCE and by the National Academy of Sciences, which continues its aid. A reobservation of all the southern stars of PIAZZI's catalogue by Professor TUCKER has recently been issued as Volume VI of the *Lick Observatory Publications*, and a similar work for all the northern stars by Professor PORTER will be an early publication of the Cincinnati Observatory. Other co-operators, both in this country and in Italy, are expected to complete the entire work in five years or less. It has now been in continuous progress nearly eight years.

Dr. SIDNEY DEAN TOWNLEY, observer in charge of the International Latitude Observatory at Ukiah, has been appointed Lecturer in Astronomy in the University of California.

The Weather Bureau of the U. S. Department of Agriculture has recently published an important bulletin, "The Climatology of California," by Professor ALEXANDER G. McADIE, Forecast Official in charge of the San Francisco office. This is a quarto volume of 270 pages and contains much valuable information for any one interested in the many climates of this wonderful State. Professor McADIE begins by discussing the controlling factors in the climate of the Pacific Coast, and these are classified under four heads, as follows:—

1. The movements of the great continental and oceanic pressure areas—the so-called permanent "highs" and "lows," as well as the movements of individual pressure areas.

2. The prevailing drift of the atmosphere in temperate latitudes from west to east.

3. The proximity of the Pacific Ocean, with a mean annual temperature near the coast-line of about 55° F., considered as a great natural conservator of heat.

4. The exceedingly diversified topography of the country for a distance of 200 miles from the coast inland.

The balance of work is given up to discussion and data under the following heads: Climate of North and Central Coast; Climate of Southern Coast; Climatology of the Great Valley; Climate of Santa Clara Valley; Local Climatology; General Precipitation Tables; Snowfall; Precipitation at High Levels; Frost, Fog, Thunderstorms, Earthquakes.

A large amount of tabulated data referring to precipitation, pressure, temperature, and wind is given. As might be expected, an almost endless variety of climates may be found in a State which has over five hundred miles of coast-line, coast ranges of mountains, great inland valleys, great deserts, and a great range of mountains with numerous peaks over 12,000 feet high. The annual precipitation varies from over sixty inches in the north coast counties and high mountain regions to less than two inches in the southeast desert regions. The temperatures vary from the breath of a blast furnace on the desert to the extreme winter cold of the mountain counties.

From the data given for the Lick Observatory we find a mean annual temperature of 52° ; mean temperature for January, 40° ; for July, 69° ; highest temperature (12 years' records), 94° ; lowest, 13° . The mean annual precipitation is thirty-two inches, while that of San Jose, only twelve miles distant in a straight line, is but fifteen inches, which furnishes a very good illustration of the effect of local topography upon the amount of rainfall. This is also strikingly illustrated in the short distance, fifty miles, and comparatively level country between San Jose and San Francisco. The rainfall at San Jose is 15 inches; at Menlo Park, 16.5 inches; at San Mateo, 21 inches; and at San Francisco, 23 inches,—an increase of eight inches in fifty miles, and the increase is nearly in proportion to the distance from San Jose.

Mr. McADIE writes very entertainingly concerning the

any alterations in the course of an eleven years' sun-spot cycle. The results so far obtained pointed very strongly to the presence of such changes. The values obtained during 1901-1902, at a decided minimum of solar activity, appeared to be materially different from those of 1903, when a new solar cycle was initiated by vigorous displays of spots and eruptions. Thus, to take one instance, a point in 60 degrees solar latitude completed a revolution round the solar axis in 36.2 days in 1901-1902, but such a point only required 29.2 days in 1903 to describe a full circle. Changes of such magnitude in the law of rotation were an entirely novel feature of the complex mechanism of the Sun. Dr. HALM pointed out the necessity of a continuation of his observations, and expressed the hope that other observatories might be induced to take up similar investigations under more favorable atmospheric conditions. —*Extract from the Scotsman.*

OFFICERS OF THE SOCIETY.

Mr. GEO. C. EDWARDS *President*
 Mr. S. D. TOWNLEY *First Vice-President*
 Mr. CHAS. S. CUSHING *Second Vice-President*
 Mr. A. O. LEUSCHNER *Third Vice-President*
 Mr. R. G. AITKEN } *Secretaries*
 Mr. F. R. ZIEL }
 Mr. F. R. ZIEL *Treasurer*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING,
 EDWARDS, LEUSCHNER, PARDEK, PIERSON, TOWNLEY, ZIEL.

Finance Committee—Messrs. CUSHING, PIERSON, LEUSCHNER.

Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.

Library Committee—Messrs. TOWNLEY, BABCOCK, Miss O'HALLORAN.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLA.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

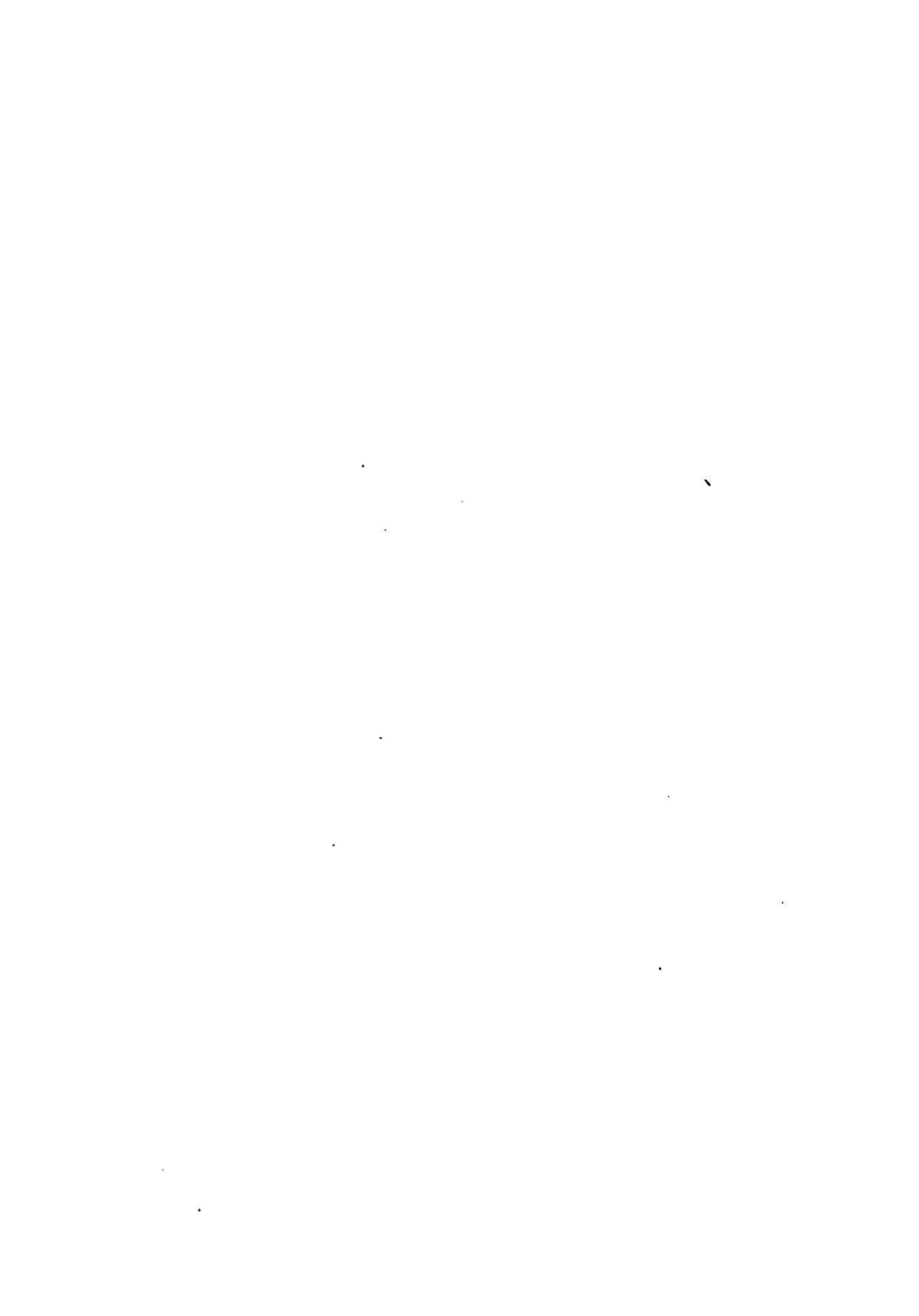
The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
 (February, April, June, August, October, December.)





CONTENTS.

The Observatory of the D. O. Mills Expedition to Chile	<i>Frontispiece</i>
	<small>PAGE.</small>
Curtis, H. D. —A Brief Review of Recent Progress in Solar Physics	133
McNeill, M. —Planetary Phenomena for July and August, 1904	141
Notices from the Lick Observatory	144
General Notes	146
Officers of the Society	155

PUBLICATIONS
OF THE
ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI - Number 67 - 1964

CATALOGUE OF THE PUBLICATIONS

OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC

1964

[Entered as second-class matter, June 15, 1964, at the Post Office at San Francisco, California]



COMMITTEE ON PUBLICATION.

ROBERT G. ATKEN, Mt. Hamilton, Cal.

FRANK SCHLESINGER, Williams Bay, Wis.

SIDNEY D. TOWNLEY, Ukiah, Cal.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, AUGUST 10, 1904. NO. 97.

CATALOGUE OF THE LIBRARY OF THE ASTRO-
NOMICAL SOCIETY OF THE PACIFIC AND OF
THE ALEXANDER MONTGOMERY LIBRARY.

PREPARED UNDER THE DIRECTION OF SIDNEY D. TOWNLEY, LIBRARIAN.

The Library of the Astronomical Society of the Pacific is composed of two main parts. In 1889 the late Mr. ALEXANDER MONTGOMERY gave the sum of twenty-five hundred dollars, which was devoted to the purpose of founding a library to be known by his name. One thousand dollars of Mr. MONTGOMERY'S gift was devoted to the purchase of books, and the balance of the Montgomery Fund was invested, and the interest is used in the maintenance of the library and in increasing the collection. The second part of the library is mainly derived from the gifts of friends of the Society, from observatories and learned societies, both at home and abroad.

The first catalogue of the library was printed in 1891 as number 18 of volume III of these Publications. Since that time the number of bound volumes (now 1,347) has increased nearly threefold. The number of pamphlets in the Library is approximately the same as the number of bound volumes. The pamphlets are not contained in the following catalogue.

The Library is located in the building of the California Academy of Sciences, 819 Market Street, San Francisco, and the books are available to all members of the Society under the usual library regulations.

Non-resident members residing within the United States may obtain books by sending ten cents in postage-stamps for

each book to the Secretary. All risk of loss must be assumed by the member and the books returned to the Society postage prepaid.

A portion of the interest derived from the John Dolbeer Fund has been used to meet the expense of printing the catalogue.

CATALOGUE OF THE LIBRARY.

BOUND BOOKS.

- ABBOT, T.: Elementary theory of the tides. London, 1888.
D, no. 292.
- ABERDEEN: Publications of the Dun Echt Observatory.
Q, vols. 1-3, nos. 674-676.
- ABOUL-WEFÂ: Théorie de la lune. Q, no. 524.
- AIRY, G. B.: Popular astronomy. London, 1887. S, 2 copies,
nos. 278-279.
- : Account of observations of transit of Venus, 1874.
December 8. Q, no. 560.
- ALEXANDER, STEPHEN: Statement and exposition of certain
harmonies of the solar system. (Smithsonian Contributions
to Knowledge No. 280.) Washington, 1875. Q, no. 1279.
- ALLEN, R. H.: Star names and their meanings. New York,
1899. O, no. 1117.
- AMERICAN JOURNAL OF SCIENCE: New Haven, 1892-1895.
O, third series, vols. 44-50, nos. 754-759.
- ANDRÉ, C. et PAYET, G.: L'astronomie pratique et les observa-
toires en Europe et Amérique. Paris, 1874-1878; D,
5 vols. 1° p.—Angleterre; 2° p.—Ecosse, Irlande, etc.;
3° p.—(par ANDRÉ et ANGOT) Etats-Unis d'Amérique;
4° p.—(par ANDRÉ et ANGOT) Observatoires d'Amérique
du Sud; 5° p.—(p. C. ANDRÉ, G. RAYET et A. ANGOT)
Observatoires d'Italie. Nos. 161-165.
- ANGOT, A.: (See *André*.)
- ANTHONY, W. and BRACKETT, C. F.: Elementary text-book
of physics. New York, 1888. O, no. 52.
- ARAGO, F.: Oeuvres complètes par J. A. Barral. Astronomie
populaire. Paris. O, vols. 1, 2, 3, 4, nos. 153-156.
- : Analyse de la vie et des travaux de Sir William Herschel.
Paris, 1843. T, no. 185.
- : Rapport pour la réimpression des oeuvres de Laplace.
Paris, 1842. T, no. 187.

- ARMAGH: Second catalogue of 3,300 stars for 1875. Dublin, 1886. o, no. 522.
- ASTRONOMICAL JOURNAL: Albany and Cambridge. f, vols. 2-4, nos. 727-729; vols. 5 and 6, no. 1086.
- ASTRONOMISCHE MITTHEILUNGEN: Zürich. Nos. 41-80, nos. 1102-1105; nos. 81-90, no. 1135.
- ASTRONOMISCHE NACHRICHTEN: Altona. 1823-1851. q, vols. 1-31, nos. 842-864. Altona and Kiel, 1851-1891. Vols. 32-128, nos. 899-944. General Register, Hamburg. q, vols. 1-120, 5 parts, nos. 836-840.
- ASTRONOMICAL NOTICES: Ann Arbor, 1858-1860. Nos. 1-20, o, no. 680.
- ASTRONOMICAL REGISTER: London, 1864-1886. Vols. 1-24, o, nos. 420-441. (Vols. 1 and 2 bound together, also 8 and 9.)
- ASTRONOMY AND ASTROPHYSICS: Northfield. Volume numbers are continuation of those of Sidereal Messenger. Vols. 11-13, o, nos. 612-614. (After vol. 13 changed to Popular Astronomy, and begun with vol. 1.)
- ASTROPHYSICAL JOURNAL: Chicago. q, vols. 1, 2, 1895, nos. 615, 616; vols. 3, 4, 1896, nos. 571, 572; vols. 5, 6, 1897, nos. 1132, 1133; vols. 7, 8, 9, 1898, 1899, nos. 1087-1089; vol. 10, 1899, no. 1134; vols. 12, 13, 14, 1900, 1901, nos. 1157-1159.
- ATHENS: L'observatoire national: Annales. Athens, 1896. Vol. 1, no. 1175.
- BACHE, M.: Calcul des éclipses du soleil par la méthode des projections. Paris, 1860. o, no. 191.
- BAILEY, F. H.: Primary phenomenal astronomy. Northville. 1886. d, no. 774.
- BAILLY, J. S.: Histoire de l'astronomie moderne. Paris, 1779-1782. q, vols. 1, 2, 3, nos. 125-127.
- : Histoire de l'astronomie indienne et orientale. Paris, 1787. q, no. 124.
- : Histoire de l'astronomie ancienne. Paris, 1781. q, no. 123.
- BAILY, F.: Account of the Rev. John Flamsteed, and his British catalogue of stars. London, 1835. q, no. 329.

- BALL, R. S.: Astronomy. New York, 1878. s, no. 39.
- BARKER, G. T.: Memoir of Henry Draper. 1837-1882. o, no. 550.
- BARNARD, E. E.: Physical and micrometrical observations of the companions to comet 1889 V (Brooks). Q, no. 762.
- BARTLETT, W. H. C.: Elements of natural philosophy—I. Mechanics. New York, 1851. o, no. 253.
- BELOPOLSKY, A. et MORINE, M.: Positions apparentes des taches solaires photographiées à Poulkovo par B. Hasselberg, 1881-1888. St. Petersburg, 1894. f, no. 1335.
- BERKELEY: Blue and Gold, 1887, no. 662; 1888, no. 46.
- BERLIN: Recheninstitut: Astronomisches Jahrbuch. Berlin, o, 1898-1900, nos. 947-949; 1901, no. 1053; 1902, no. 1120; 1903, 1904, nos. 1253, 1254.
- BICKERTON, A. W.: The romance of the earth. London, 1900. D, no. 1207.
- : The romance of the heavens. London, 1901. Two copies. D, nos. 1195, 1206.
- BIGELOW, F. H.: The solar corona discussed by spherical harmonics. (Smithsonian Contributions to Knowledge No. 691.) Washington, 1889. f, no. 100.
- BIGOURDAN, M. G.: Mesures d'étoiles doubles; in "Double Stars." Q, no. 742.
- BIOT, J. B.: Nouvelles études sur les réfractions atmosphériques. Paris. Q, no. 262.
- : Recherches sur les réfractions extraordinaires. Paris, 1810. Q, no. 510.
- : Traité élémentaire d'astronomie physique. Paris, 1841; vols. 1, 2-3, nos. 118, 119. Paris, 1847; vols. 4-5, no. 787.
- BIOT et LEVERRIER: Memoirs—various. Paris, 1838-1840. o, no. 513.
- BIRMINGHAM, J.: The red stars. Dublin, 1877. Q, no. 555.
- BLAKE, J. F.: Astronomical myths. London, 1877. o, no. 295.
- BOHLIN, K.: Formeln und Tafeln zur Berechnung der allgemeinen Störungen. Upsala, 1896. Q, no. 745.
- BOSS, L.: (See *Leipzig*.) Astronomische Gesellschaft.
- BOSSERT: (See *Göttingen*.)

- BOUCHET, U.: Hémérologie ou traité pratique complet des calendriers. Paris, 1868. o, no. 167.
- BOWMAN, C. G.: Report of total solar eclipse, July 29, 1878. Q. no. 103, in "Solar Eclipses 1858-1885."
- BRACKETT, C. F.: (See *Anthony*.)
- BRENNER, LEO: Mars-Beobachtungen, 1896-1897. Berlin, 1898. Q, no. 1061.
- BRETON, P.: Étude sur les orbites hyperboliques et sur l'existence probable d'une réfraction stellaire. Paris, 1880. o, no. 176.
- BREWSTER, D.: More worlds than one. London, 1888. D, no. 276.
- BRINKLEY, J.: Astronomy revised and rewritten by J. W. Stubbs and F. Brünnow. London, 1886. D, no. 283.
- BROWN, A. D., and WINTERHALTER, A. G.: Annular eclipse of the sun. March 15-16, 1885. (Appendix II, Washington Observations, 1882.) In "Solar Eclipses 1858-1885." Q, no. 103.
- BROWN, R.: The law of cosmic order. London, 1882. o, no. 290.
- BRÜNNOW, F.: (See *Brinkley, J.*) Spherical astronomy. Berlin, 1865. o, no. 321. Astronomical Notices, nos. 1-20. Ann Arbor, 1858-1860. o, no. 680.
- BRUSSELS: L'observatoire royal: Annales. Brussels. Q, vols. 1-7, nos. 865-871.
- BUENOS AYRES: Oficina meteorologica Argentina: Anales, F, 1893, vols. 9-11, nos. 805-808; 1898, vol. 12, pt. I, no. 1038; 1899, vol. 12, pt. II, no. 122; 1900, vol. 13, no. 256; 1901, vol. 14, no. 1263.
- BURNHAM, S. W.: Double-star observations, June and July, 1889. In "Double Stars." Q, no. 742.
- BURR, E. F.: Ecce cælum; or, Parish astronomy. New York, 1897. D, no. 20.
- BURRITT, E. H.: Geography of the heavens. D, four copies, nos. 25-28. (See *Mattison, H.*)
- BYRD, M. E.: Laboratory manual in astronomy. Boston, 1899. D, no. 1148.

CALLANDREAU, M. O.: Étude sur la théorie des comètes périodiques. Calcul des variations séculaires des éléments des orbites. Paris. Q, no. 762.

CAMBRIDGE (England): Astronomical observations made at the observatory. 1872-1875. F, no. 974.

—: Harvard College Observatory: *Annals*. F, vol. 3, 1067; vols. 5, 8, nos. 1032, 1033; vol. 12, 1182; vols. 13-15, nos. 890-892; vols. 16, 17, nos. 1068, 1069; vol. 23 no. 1183; vol. 24, no. 893; vol. 25, no. 1184; vols. 26, 27, nos. 894, 895; vol. 28, no. 1185; vol. 29, no. 896; vols. 32, 33, nos. 1136, 1137; vol. 34, no. 897; vol. 35, no. 1186; vol. 36, no. 1070; vols. 37, 38, nos. 1299, 1300; vol. 44, no. 1301; vol. 45, no. 1187.

CAMPBELL, W. W.: Handbook of practical astronomy. Ann Arbor, 1891. O, no. 471.

CAPE OF GOOD HOPE OBSERVATORY: Results of meridian observations, 1861-1865. London, 1897, O, no. 709; 1866-1870, Edinburgh, 1900, O, no. 1197; 1877, Edinburgh, 1901, O, no. 1198; 1878-1879, Edinburgh, 1901, O, no. 1199; 1879-1881, London, 1883, O, no. 556; 1882-1884, London, 1887, O, no. 557; 1885-1887, London, 1894, F, no. 620; 1888-1889, London, 1895, F, no. 707; 1890-1891, London, 1895, F, no. 708; 1892-1895, London, 1896, F, no. 969; 1896-1897, Edinburgh, 1901, F, no. 1200; 1898-1899, Edinburgh, 1901, F, no. 1201.

—: Appendix to Cape Meridian Observations, 1890-1891. F, no. 761.

—: Catalogue of 1,905 stars (1865.0). London, 1899. O, no. 1196.

—: Catalogue of 1,713 stars (1885.0). London, 1894. F, no. 619.

—: Catalogue of 3,007 stars (1890.0). London, 1898. F, no. 1144.

—: Heliometer observations (stellar parallax). London, 1893. O, no. 618.

—: *Annals* (Photographic Durchmusterung): Vol. III, London, 1896, F, no. 704; vol. IV, London, 1897, F, no. 968; vol. V, Edinburgh, 1900, F, no. 1217.

—: *Annals* (solar parallax): Vol. VI, London, 1897, F, no. 705; vol. VII, London, 1896, F, no. 706.

- CAREY, G. W.: Astronomy as it is known at the present day. London, 1836. o. no. 299.
- CARPENTER, J.: (See *Nasmyth*.)
- CHALMERS, T.: Discourses on Christian revelation. Edinburgh, 1885. d, no. 286.
- CHAMBERS, G. F.: Handbook of descriptive and practical astronomy. Oxford, 1890. o. vols. 2, 3, nos. 312, 313; vols. 1, 2, 3, nos. 169-171.
- CHAPIN, F. H.: Mountaineering in Colorado. Boston, 1889. t, no. 525.
- CHAUVENET, W.: Manual of spherical and practical astronomy. Philadelphia, 1889. o. 2 vols., nos. 82, 83; vol. I, 1863, no. 241.
- CHRISTIE, J. R.: An introduction to the elements of practical astronomy. London, 1853. o. two copies, nos. 297, 298.
- CHRISTIE, W. H. M.: Manual of elementary science—Astronomy. London, 1884. s. no. 288.
- CHRISTIANA: Observatory: Zonenbeobachtungen $+64^{\circ} 50'$ to $+70^{\circ} 10'$. 1888. f, no. 703.
- CHURCH, A. E.: Elements of the differential and integral calculus. New York, 1851. o. no. 252.
- CINCINNATI: Observatory: Catalogue of 1,340 proper-motion stars, 1892. q, no. 751.
- : (See *Göttingen*.)
- CLARK, L.: Manual of the transit instrument. London, 1884. d, no. 304.
- CLARK, L., and SADLER, H.: The star guide. London, 1886. q, no. 242.
- CLERKE, A. M.: Popular history of astronomy during the XIX century. Edinburgh, 1887. Two copies. o, nos. 314, 315.
- : The system of the stars. London, 1890. o. no. 491.
- : Problems in astrophysics. London, 1903. o, no. 1259.
- COFFIN, J. H.: Orbit and phenomena of a meteoric fireball. Philadelphia, 1869. q, no. 1278.
- COLAS, J. A.: Poole Bros.' celestial handbook. Companion to planisphere. Chicago, 1892. q, no. 609.

- COMSTOCK, G. C.: A text-book of astronomy. New York, 1901. D, no. 1150.
- : Method of least squares. Boston, 1895. D, no. 1151.
- CONTARMO, F.: Osservazioni della nuova cometa di Holmes. 1892. Q, no. 762.
- CORDOBA: Observatorio nacional Argentino: Resultados. Buenos Ayres, F; vol. 15, 1896, no. 736; vol. 18, 1900, no. 1172.
- COSTARD, G.: History of astronomy. London, 1767. Q, no. 294.
- CROVA, M. A.: Mesure de l'intensité calorifique des radiations solaires. Paris, 1876. Q, no. 179.
- CRULS, L.: Commission d'exploration du plateau central du Brésil. Atlas. Rio de Janeiro, 1894. F⁵, 4 vols., nos. 628-631.
- DAVIS, H. S.: (See *Göttingen*.)
- DEICHMÜLLER, F.: (See *Leipzig*.) Astronomische Gesellschaft.
- DELAMBRE, J. B. J.: Histoire de l'astronomie ancienne. Paris, 1817. sq. Q, 2 vols., nos. 116, 117.
- : Histoire de l'astronomie du moyen-age. Paris, 1819. sq. Q, no. 115.
- : Histoire de l'astronomie au dix-huitième siècle. Paris, 1827. sq. Q, no. 149.
- : Astronomie théorique et pratique. Paris, 1814. 3 vols., sq. Q, nos. 141-143.
- DELAUNAY, C.: Cours élémentaire d'astronomie. Paris, 1885. D, no. 182.
- DONNER, A.: Beobachtungen von Cometen. Helsingfors, 1888. Q, no. 762.
- DOOLITTLE, C. L.: A treatise on practical astronomy as applied to geodesy and navigation. New York, 1900. O, no. 1156.
- DORPAT: Kaiserliche Universitäts Sternwarte. Beobachtungen. F, vol. 18, no. 733; vol. 19, no. 1302.
- DOWNING: Precession tables. Edinburgh, 1899. Q, no. 1075.
- DRAYSON, A. W.: Common sights in the heavens. London, 1862. D, no. 300.

- DREYER, J. L. E.: Tycho Brahe. Edinburgh, 1890. o, no. 1147.
- : Index catalogue of nebulae found 1888-1894. London, 1895. Q, no. 743.
- DUBLIN: Royal Irish Academy: Transactions. Dublin, 1877. Q, vol. 26, part VII, no. 555.
- : Second Armagh catalogue of 3,300 stars for 1875. o, no. 522. (See *Armagh*.)
- DUBOIS, E.: Les passages de Vénus. Paris, 1873. D, no. 184.
- DUN ECHT: Observatory: Publications. Aberdeen, 1876. Q, vols. 1-3, nos. 674-676.
- DUNÉR et ENGSTRÖM: (See *Lund*.)
- DUNKIN, E.: The midnight sky. London, 1879. Q, two copies, nos. 263, 264.
- DUNSINK: Observations. Dublin. F, parts 1-4, no. 717; 5-7, no. 718.
- EDINBURGH: Royal Observatory: Astronomical observations. 1878-1886. Edinburgh, 1886. sq. Q, vol. 15, no. 209.
- : Catalogue of Crawford Library. Edinburgh, 1890. F, no. 763.
- ENGSTRÖM et DUNÉR: (See *Lund*.)
- EWING, T.: Astronomy and geography. Edinburgh, 1859. D, no. 40.
- FABRY, L.: Thèses présentées à la faculté des sciences de Paris. (Studies on comet orbits.) Marseilles, 1893. Q, no. 749.
- FAYE, H.: Cours d'astronomie de l'école polytechnique. Paris, 1881-1883. 2 vols., o, nos. 239, 240.
- : Sur l'origine du monde. Paris, 1885. o, no. 158.
- FEARNLEY and GEELMUYDEN: (See *Christiania; Leipzig*.)
Astronomische Gesellschaft.
- FINDLATER, A.: Chambers's elementary science manuals—
Astronomy. London and Edinburgh, 1884. S, no. 287.
- FINLAY, W. H.: Star correction tables. F, no. 761.
- FLAGSTAFF: Lowell Observatory: Annals. Boston and New York. Q, 1898; vol. 1, no. 967. Cambridge, 1900; vol. 2, no. 1178.

- FLAMMARION, C.: Études et lectures sur l'astronomie. Paris, 1867-1880. 9 vols., s, nos. 132-140.
- : Les étoiles et les curiosités du ciel. Paris, 1890. Q, no. 148.
- : Astronomie populaire. Paris, 1890. Q, two copies. nos. 147, 218.
- : Catalogue des étoiles doubles et multiples. Paris, 1878. o, no. 166.
- : L'astronomie et ses fondateurs—Copernic. Paris. s, no. 539.
- : Atlas céleste. Paris, 1887. F⁵, no. 160.
- : La planète Mars. Paris, 1892. Q, no. 750.
- FRANCOEUR, L. B.: Uranographie; ou, Traité élémentaire d'astronomie. Paris, 1853. o, no. 159.
- FROST, E. B.: (See *Scheiner*.)
- GAZAN, A.: Constitution physique du soleil. Antibes, 1873. o, no. 193.
- GEORGETOWN: Observatory: The photochronograph: Photographic transits. Washington, 1891-1896. Q, no. 744.
- GILBERT, P.: Les preuves mécaniques de la terre. Paris, 1883. o, no. 177.
- GILL, D.: (See *Cape of Good Hope*.)
- GILLISS, J. M.: An account of the total eclipse of the sun, September 7, 1858. (Smithsonian Contributions to Knowledge, 100.) Q, no. 103, in "Solar Eclipses, 1858-1885."
- GINOT-DESROIS: Du calendrier astronomique et perpétuel. Paris, 1861. o, no. 188.
- GIRARD, J.: Recherches sur les tremblements de terre. Paris, 1890. D, no. 878.
- GÖTTINGEN: Königliche Sternwarte: Astronomische Mittheilungen, 1894. Q, parts 3, 4, no. 690.
- : Various catalogues of stars. Göttingen, Melbourne (2), Cincinnati, Bossert, Kiel, Davis, Hilfliser. Q, no. 716.
- GOULD, B. A.: The transatlantic longitude, 1869. Q, no. 1275.
- GREENWICH: Royal Observatory: New seven-year catalogue of 2,760 stars, 1864. London. F, no. 93.
- : Ten-year catalogue of 4,059 stars for 1880. London, 1889. F, no. 174.

- GREENWICH: Royal Observatory: Five-year catalogue of 258 stars for 1890. London, 1893. F, no. 719.
- : Second ten-year catalogue of 6,892 stars for 1890. Edinburgh, 1900. F, no. 1214.
- : Astronomical results. London, 1864-1867. F, nos. 1001-1004; 1869-1886, nos. 1005-1021.
- : Introduction to Greenwich observations. F, 1877-1886, nos. 1022-1030.
- : Observations, 1887, no. 173; 1888, no. 153; 1889, no. 580; 1890, no. 579; 1891, no. 581; 1892, no. 650; 1893, no. 582; 1894, no. 583; 1895, no. 966; 1896, no. 1045; 1897, no. 1209; 1898, no. 1210; 1899, no. 1211.
- : Appendix 3 to Greenwich observations for 1887. London, 1889. F, no. 175.
- : Results of Greenwich magnetic and meteorologic observations. 1874. F, no. 994.
- : Reduction of Greenwich meteorological observations. Part III—Temperature of the air. London, 1895. F, no. 666.
- : Spectroscopic and photographic results, 1878-1882. F, nos. 995-999.
- : Description of altazimuth of Greenwich observatory. 1847. F, no. 991.
- : Description of transit-circle of Greenwich observatory. 1852. F, no. 992.
- : Description of the reflex zenith tube, Greenwich observatory. 1854. F, no. 993.
- : Description of Greenwich time-signal system. 1879. F, no. 990.
- GREGORY, DAVID: Elements of physical and geometrical astronomy. London, 1726. O, vol. 1, no. 1346; vol. 2, no. 1347.
- GUILLEMIN, A.: The heavens. London, 1883. O, two copies, nos. 265, 266.
- : The world of comets. London, 1887. Q, no. 293.
- GUMMERS, JOHN: An elementary treatise on astronomy. Philadelphia, 1853. O, no. 277.
- GUTHNICK, PAUL: Neue Untersuchungen über den veränderlichen Stern α Ceti (Mira). Halle, 1901. F, no. 1255.

- GYLDEN, H.: Nouvelles recherches sur les séries employées dans les théories des planètes. Stockholm, 1892. Q, no. 747.
- : Traité analytique des orbites absolus des huit planètes principales. Stockholm, 1893. Q, no. 748.
- HALL, A.: Orbits of Oberon and Titania. (Appendix I, Washington Observations, 1881.) Washington, 1885. Q, no. 107.
- : The six inner satellites of Saturn. (Appendix I, Washington Observations, 1883.) Washington, 1886. D, no. 108 (bound with 107).
- : Saturn and its rings. (Appendix II, Washington Observations, 1885.) Washington, 1889. Q, no. 741.
- : Observations of double stars. (Appendix I, Washington Observations, 1888.) Q, no. 742.
- HARKNESS, W.: Solar parallax and related constants. (Appendix III, Washington Observations, 1885.) Washington, 1891. Q, no. 508.
- HARLEY, T. H.: Moon lore. London, 1885. O, no. 268.
- HARZER, P.: Die Säculären Veränderungen der Bahnen der grossen Planeten. Leipzig, 1895. Q, no. 746.
- HAUGHTON, S.: Manual of tides and tidal currents. (Fourth edition.) London and New York, 1870. S, no. 289.
- HERSCHEL, J. F. W.: Outlines of astronomy. London, 1887. O, two copies, nos. 53, 54.
- : Catalogue of 10,300 multiple and double stars. London, 1874. Q, no. 91.
- HILL, G. W.: Astronomical papers for American Ephemeris and Nautical Almanac. Washington, F; vol. 4, 1882, no. 206; vol. 3, 1891, no. 536.
- HIMMEL UND ERDE: Berlin, Q; vol. 1, 1888-1889, no. 80; vol. 2, 1889-1890, no. 1090; vol. 4, 1891-1892, no. 1091; vol. 5, 1892-1893, no. 1092; vol. 6, 1893-1894, no. 1093; vol. 7, 1894-1895, no. 1094; vol. 8, 1895-1896, no. 1095; vol. 9, 1896-1897, no. 1282; vol. 10, 1897-1898, no. 1096.
- HIND, J. R.: The comets. London, 1852. O, no. 296.
- : The comet of 1556. London, 1857. D, no. 303.
- : An introduction to astronomy. London, 1863. D, no. 284.

- HIRN, G. A.: *La conservation de l'énergie solaire*. Paris, 1883. q. no. 180.
- : *Mémoire sur les conditions d'équilibre des anneaux de Saturne*. Paris, 1872. q. no. 181.
- : *Mémoire sur les propriétés optiques de la flamme des corps en combustion*. Paris, 1873. o. no. 189.
- HOLDEN, E. S.: *Observations and papers* (q. no. 105), containing subject index to publications of the U. S. Naval Observatory, 1845-1875. (Appendix I, Washington Observations, 1876.) *Investigation of objective and micrometers of 26-inch equatorial*. (Appendix I, Washington Observations, 1877.) *The multiple star $\Sigma 748$* . (Appendix II, Washington Observations, 1877.) *Catalogue of the library of U. S. Naval Observatory. Part I—Astronomical Bibliography*.
- : *Monograph of central parts of Orion nebula*. (Appendix I, Washington Observations, 1878.) Washington, 1882. q. no. 106.
- : *Memorials of W. C. and G. P. Bond*. San Francisco, 1897. o. no. 789.
- : *Eclipse expedition to Caroline Island, May, 1883*. (Memoirs National Academy of Sciences.) Washington, 1883. f. no. 102.
- : *List of red stars*. q. no. 752.
- HOLETSCHEK, J.: *Untersuchungen über Grösse und Helligkeit der Kometen und ihrer Schweife. I*. Wien, 1896. f. no. 753.
- HONGKONG: *Observations and researches made at Hongkong Observatory in 1884*. Hongkong, 1885. q. no. 1318.
- HONORÉ, C.: *Loi du rayonnement thermique solaire*. Montévidéo, 1896. q. no. 793.
- : *El sol*. Montévidéo, 1897. o. no. 875.
- HOOGWERFF, J. A.: *Magnetic observations at the United States Naval Observatory, 1888-1889*. (Appendix I, Washington Observations, 1886.) Washington, 1890. q. two copies. nos. 506 and 1344.
- HOUZEAU, J. C.: *Vade mecum de l'astronomie*. Bruxelles, 1882. o. no. 417.

- HOUSSEAU, J. C., et LANCASTER, A.: *Bibliographie generale de l'astronomie*. Bruxelles, 1882, 1887, 1889. 3 vols., Q, nos. 144-146.
- HOWE, H. A.: *Elements of descriptive astronomy*. Boston, 1897. O, no. 1155.
- HUGGINS, WM.: (See *London*.)
- HUMBOLDT, A. VON: *Cosmos*. London, 1888. 5 vols., D, nos. 271-275.
- JACOBY, H.: *Practical talks by an astronomer*. New York, 1902. D, no. 1154.
- JEANS, G.: *Practical astronomy for the unlearned*. London, 1856. D, no. 331.
- JEANS, H. W.: *Handbook for the stars*. London, 1888. Q, no. 267.
- JOHNSTON, A. K.: *School atlas of astronomy*. Edinburgh, 1886. Four copies. Q, nos. 86-89.
- KANE, ELISHA KENT: *Astronomical observations in the arctic seas*. Philadelphia, 1860. Q, no. 1280.
- KARLSRUHE: *Grossherzogliche Sternwarte; Veröffentlichungen*. Karlsruhe, F, 1892, vol. 4, no. 735; 1896, vol. 5, no. 734.
- KASAN: *L'observatoire: Observations des étoiles de la zone entre $+75^{\circ}$ et $+80^{\circ}$* . Kasan, 1885. Q, 2 vols., nos. 98, 99.
- KEDZIE, J. H.: *Speculations. solar heat, gravitation, and sun-spots*. Chicago, 1886. D, no. 257.
- KIEL: (See *Göttingen*.) *Publicationen der Sternwarte*. Parts 3, 6, 9. Kiel. Q, no. 762 (bound under title—Various authors). Part 8. Kiel, 1893. Q, no. 752.
- KIRKWOOD, D.: *Comets and meteors*. Philadelphia, 1873. D, no. 255.
- : *The asteroids*. Philadelphia, 1888. D, three copies, nos. 44, 45, 254.
- KLEIN, H. J.: *Anleitung zur Durchmusterung des Himmels. Astronomische Objecte*. Braunschweig, 1882. O, no. 244.
- KNOTT, GEORGE: *Observations of twenty-three variable stars*. London, 1899. Q, no. 1060.

KÖNIGSBERG: Astronomische Beobachtungen auf der Königlich-Universitäts-Sternwarte. Parts 38, 39. Königsberg, 1899. F, no. 1317.

KÖNIGSTUHL-HEIDELBERG: Publicationen des Astrophysikalischen Observatoriums. Karlsruhe, 1902. Q, no. 1341.

KRIEGER, J. N.: Mond-Atlas. Triest, 1898. F, part 1, no. 872.

KREUTZ, H.: Untersuchungen über das Cometensystem, 1843, I; 1880, I; und 1882, II. Parts I and II, Der grosse September Comet 1882 II (Publicationen der Sternwarte in Kiel, parts 3 and 6). Kiel, 1888-1891. Q, no. 762.

—: Ueber die Bahn des Cometen 1873 V. (Publicationen der Sternwarte in Kiel, part IX, no. 2.) Kiel, 1894. Q, no. 762.

—: Bahnbestimmungen des Planeten (266) Weringia. (Publicationen der Sternwarte in Kiel, part IX, no. 3.) Kiel, 1894. Q, no. 762.

KRUEGER, A.: (See *Leipzig*.) Astronomische Gesellschaft: Catalog der Farbigen Sterne. Kiel, 1894. (Publicationen der Sternwarte in Kiel, part VIII.) Q, no. 752.

LALANDE, J. DE: Tafeln der fünfstelligen Logarithmen. Leipzig, 1876. T, no. 259.

LANCASTER, A.: Notes biographiques sur J. S. Houzeau. Bruxelles, 1889. Q, no. 111

—: (See *Houzeau, J. C.*)

LANGLEY, S. P.: Researches on solar heat. Washington, 1884. F, no. 210.

—: Report of total solar eclipse, July 29, 1878 (in "Solar eclipses 1858-1885"). Q, no. 103.

—: The new astronomy. Boston and New York, 1889. Q, two copies, nos. 84, 85.

LAPLACE, P. S. DE: Traité de mécanique céleste. Paris, 1798-1825. 5 vols., Q, nos. 213-217.

—: Exposition du système du monde. Paris, 1835. Q, no. 212.

—: Précis de l'histoire de l'astronomie. Paris, 1865. O, no. 168.

- LA PLATA: Observatorio de; Anuario, 1887. Buenos Ayres, 1886. s, no. 96.
- LEDGER, E.: The sun; its planets and their satellites. London, 1882. o, no. 788.
- LEIDEN: Sternwarte: Annalen. Haag, F; vols. 3, 4, 1872, nos. 221, 222; vols. 5, 6, 1890, nos. 695, 696; Q, vol. 7, 1897, no. 1042; vol. 8, 1899, no. 1262.
- LEIPZIG: Astronomische Gesellschaft: Vierteljahresschrift. o, vol. 24, Leipzig, 1889, no. 114; vols. 25-27, Leipzig, 1890-1892, nos. 782-784; vol. 28, Leipzig, 1893, no. 1131; vols. 29, 30, Leipzig, 1894-1895, nos. 785, 786; Catalog, 1890, sq. F, part 3, no. 721; 1890, part 4, no. 722; 1892, part 5, no. 724; 1894, part 6, no. 725; 1895, part 10, no. 726; 1890, part 14, no. 723.
- LEVERRIER, J.: (See *Biot et Leverrier*.)
- LEON, LUIS G.: Las constelaciones. Mexico, 1902. o, no. 1261.
- LISBON: Observatorio: Observations de la planète Mars, 1892. Lisbon, 1895. Q, no. 740.
- : Eclipse of sol, 1900. Q, no. 1319.
- LITTROW, J. J. VON: Die Wunder des Himmels. Berlin, 1865. o, no. 464.
- : Dioptrik. Vienna, 1830. o, no. 549.
- LOCKYER, J. N.: Studies in spectrum analysis. New York, 1878. D, no. 50.
- : Star-gazing, past and present. London, 1878. o, four copies, nos. 306-309.
- : The movements of the earth. London, 1887. D, no. 291.
- : The meteoritic hypothesis. London, 1890. o, no. 490.
- LODGE, OLIVER: Pioneers of science. London, 1893. D, no. 1146.
- LONDON: Royal Astronomical Society: Memoirs. London. Q, vol. 48, part II, 1885, no. 1036; vol. 49, part II, 1890, no. 1037; vol. 50, 1892, no. 1035; vol. 51, 1895 no. 1034. Monthly Notices. o, vols. 1-22, nos. 442-463; vols. 23-25, nos. 775-777; vols. 26-29, nos. 467-470; vol. 30, no. 472;

LONDON: Royal Astronomical Society: *Memoirs (continued)*.

vol. 31. no. 778: vols. 32-46. nos. 474-488: vols. 45, 46, nos. 533-534: vols. 47-49. nos. 530-532: vols. 50-55. nos. 643-648: vol. 56. no. 1129: vol. 57. no. 879: vol. 58. no. 1080: vol. 59. no. 1130: vol. 60. no. 1168: vol. 61. no. 1169: Index vols. 1-29. no. 779: Index vols. 30-52. no. 780.

—: British Astronomical Association: *Memoirs*. o. vols. 1, 2. no. 1057: vols. 3, 4. no. 1058: vols. 5, 6. no. 1083: vols. 7, 8. no. 1166: vols. 9, 10. no. 1265. *Journal*: o. vols. 1-7. nos. 823-829: vols. 8, 9. nos. 1081, 1082: vols. 10, 11. nos. 1164, 1165: vol. 12. no. 1266.

—: Indian eclipse, 1898. London, 1899. o. no. 1047.

—: Nautical Almanac and Astronomical Ephemeris. o. 1895-1901. no. 950-956: 1902. no. 1050: 1903. no. 1119: 1904. no. 1251: 1905. no. 1252.

—: Sir William Huggins's Observatory: *Publications*. London, 1899. Vol. I. F⁵. no. 1141.

LONG, R.: *Astronomy, in five books*. Cambridge, 1742. o. no. 79.

LOOMIS, E.: *The recent progress of astronomy, especially in the United States*. New York, 1851. o. no. 599.

—: *A treatise on astronomy*. New York, 1889. o. no. 65.

—: *Treatise on meteorology*. New York, 1890. o. no. 261.

—: *Elements of astronomy*. New York, 1889. d, three copies, nos. 66-68.

—: *An introduction to practical astronomy*. New York, 1889. o, three copies, nos. 62-64.

LUND: DUNÉR et ENGSTRÖM: *Observations des étoiles entre + 35° et 40°*. Lund, 1896. F, 2 parts. nos. 730, 731: vol. 3, 1900. sq. F, no. 1285.

MADISON: Washburn Observatory: *Publications*. Madison. Vol. I, 1881, o, three copies, nos. 245, 514, 1257: vol. II, 1883, o, two copies, nos. 246, 515: vol. III, 1885, o, two copies, nos. 247, 516: vol. IV, 1885, o, two copies, nos. 248, 517: vol. V, 1886, o, two copies, nos. 249, 518: vols. VI and VII, 1890-1892. o. no. 692: vol. IX, 1896, o, no. 693.

- MADISON: Wisconsin Academy of Sciences, Arts, and Letters. Transactions. Madison. o, 1893, vol. 9, parts 1 and 2, nos. 820, 821; 1895, vol. 10, no. 822; 1898, vol. 11, no. 970.
- MÄDLER, J. H.: Der Wunderbau des Weltalls oder Populäre Astronomie. Strassburg, 1882. o, no. 465.
—: Atlas. Strassburg, 1882, no. 466.
- MADRAS: Taylor's general catalogue of stars, 1835.o. Edinburgh, 1901. q, no. 1215.
—: Meridian-circle observations. q, 1862-1870, 3 vols., nos. 552-554; 1874-1876, no. 595; 1877-1887, vols. 6-8, nos. 596-598; 1899, vol. 9, no. 1139.
- MADRID: Observatorio: Resumen de las observaciones meteorológicas. o, 1884-1885, nos. 237, 238; 1886, no. 319; 1887, no. 526; 1890, no. 622; 1891-1892, no. 624.
—: Resumen de las observaciones meteorológicas de provincias. o, 1893-1894, no. 790; 1889, no. 791.
—: Observaciones meteorológicas, 1886-1887. o, no. 236; 1888-1889, no. 320; 1890-1891, no. 623; 1892-1893, two copies, nos. 625, 626; 1894-1895, no. 792; 1895-1896, no. 1055; 1896-1897, no. 1054; 1898-1899, no. 121.
- MARSH, C. C.: A report upon some of the magnetic observatories of Europe. Washington, 1901. q, no. 1269.
- MATTISON, H.: Atlas to illustrate Burrit's Geography of the Heavens. New York, 1856. f, four copies, nos. 128-131.
- MAUNDER, E. W.: (See *London*.)
- MAYER, W.: Das Weltgebäude. Leipzig, 1898. o, no. 873.
- MEE, A.: Observational astronomy. Cardiff, 1893. o, no. 586.
- MELBOURNE OBSERVATORY: Results of astronomical observations of Melbourne Observatory. 1879. Vol. V, o, no. 1258.
—: (See *Göttingen*.)
- MENDIZÁBEL-TAMBORREL: Tables des logarithmes à huit décimales. Paris, 1891. f, no. 835.
- MEXICO: (See *Tacubaya*.)
—: Sociedad Científica "Antonio Alzate": Memorias. o, vols. 3-9, 1889-1895, nos. 794-800; vol. 10, 1896-1897, no. 1084; vol. 12, 1898, no. 1170; vol. 15, 1900, no. 1171.

- MILLER, R. K.: The romance of astronomy. London, 1882.
D, no. 285.
- MILLER, W.: The heavenly bodies. London, 1883. No. 280.
- MITCHEL, O. M.: The planetary and stellar worlds. New York, 1874. D, four copies, nos. 12-15.
- : Popular astronomy. New York, 1876. D, four copies, nos. 21-24.
- MOIGNO, L'ABBÉ: Le Révérend Père Secchi, sa vie. Paris, 1879. D, no. 183.
- MORINE, M.: (See *Belopolsky*.)
- MORTON, E. J. C.: Heroes of science—Astronomers. London. D, no. 1153.
- Moscow: L'observatoire: Annales. 1893. Q, vol. 3 (2d series), no. 691.
- MOULTON, F. R.: An introduction to celestial mechanics. London, 1899. O, no. 1208.
- MOUNT HAMILTON: Lick Observatory: Publications. Sacramento, sq. F, 1887, vol. 1, no. 208; 1894, vol. 2, no. 607; 1894, vol. 3, no. 608; 1900, vol. 4, no. 1220; 1901, vol. 5, no. 1221.
- : Contributions: No. 1. Reports on the observations of the total eclipse of the sun, January 1, 1889; Sacramento, 1889; O, no. 250.—No. 2. Reports on the observations of the total eclipse of the sun, December 21-22, 1889; Sacramento, 1891; O, no. 546.—No. 3. Terrestrial atmospheric absorption of the photographic rays of light; Sacramento, 1893; O, no. 575.—No. 4. Report on total eclipse of the sun, April 16, 1893; Sacramento, 1895; O, no. 605.—No. 5. Meteors and sunsets, 1893-1895; Sacramento, 1895; O, no. 606.
- : Bulletins of Lick Observatory. Berkeley, 1900-1902. Q, nos. 1-26; vol. 1, no. 1271.
- MÜLLER, G.: Die Photometrie der Gestirne. Leipzig, 1897. O, no. 1289.
- MUNICH: Sternwarte bei Bogenhausen: Neue Annalen. Munich. F, vol. 1, Catalog 33,082 Sterne, 1890, no. 714; vol. 2, Catalog 13,200 Sterne, 1891, no. 715; vol. 3, 1898, no. 1173.

- NAEGAMVALA, KAVASJI DADABHAI: Report on the total solar eclipse of January 21-22, 1898. Bombay, 1902. Q, no. 1212.
- NASMYTH, J., and CARPENTER, J.: The moon. London. 1885. O, no. 56.
- NEISON, E.: The moon. London, 1870. O, no. 55.
- NEUCHATEL, (J. Kilfilser): (See *Göttingen*.)
- NEWCOMB, S.: Popular astronomy. School edition. New York, 1889. Five copies, nos. 57-61.
- : The stars. New York, 1901. O, no. 1145.
- : Orbit of Neptune. (Smithsonian Contributions to Knowledge, no. 199.) Philadelphia, 1866. Q, no. 276.
- : General integrals of planetary motion. (Smithsonian Contributions to Knowledge, no. 281.) Washington, 1874. Q, no. 1277.
- : Uranian and Neptunian systems. (Appendix I. Washington Observations for 1873.) Washington, 1875. Q, no. 104.
- : Orbit of Uranus. (Smithsonian Contributions to Knowledge, no. 262.) F, no. 1000.
- : Report on the total solar eclipse, July 29, 1878. (Extract from Appendix III, Washington Observations, 1876.) Q, no. 103 (in "Solar Eclipses 1858-1885").
- : Motion of the moon. (Appendix II, Washington Observations, 1875.) Washington, 1878. Q, no. 110.
- : Astronomical papers for American Ephemeris and Nautical Almanac. Washington, F; vol. 1, 1882, no. 205; vol. 2, 1891, no. 535; vol. 3 (with HILL, G. W.), 1891, no. 536; vols. 5, 6, nos. 687, 688.
- : Reminiscences of an astronomer. Cambridge, 1903. O, no. 1345.
- NEW YORK: New York Mathematical Society: Bulletin. 1892-1894. O, vols. 1-3, nos. 801-803.
- : American Mathematical Society: Bulletin. New York. O, vol. 1, 1895, no. 804; vols. 2-4, 1895-1898, nos. 1122-1124; vol. 5, 1898-1899, no. 1066; vol. 6, 1900, no. 1162; vol. 7, 1901, no. 1163; vol. 8, 1901-1902, no. 1268.

- NICE: L'observatoire: Annales. Paris. F, vol. 1, 1899, no. 1072; vols. 4-6, 1895-1897, nos. 700-702; vol. 7, 1900, no. 1174; vol. 1 (atlas), 1899, ob. F, no. 1073; vol. 3 (atlas), 1890, ob. F, no. 651.
- : Monographie de l'observatoire. Paris, 1892. F^s, no. 652.
- NOBLE, W.: Hours with a 3-inch telescope. London, 1867. D, five copies, nos. 34-38.
- NORMAND, J. A.: Mémoire sur les occultations d'étoiles par les planètes. Paris, 1876. Q, no. 178.
- NORTHFIELD: Catalogues of stars and nebulæ. Northfield, 1890. Q, no. 686.
- NORTON, W. A.: An elementary treatise on astronomy. New York, 1859. O, no. 49.
- NYRÉN, M.: Déclinaisons moyennes des étoiles principales, 1885.O. St. Petersburg, 1893. F, no. 732.
- OBSERVATORY (THE): London. O, vols. 1-11, 1877-1888, nos. 492-502; vol. 12, 1889, no. 1126; vols. 13-19, 1890-1896, nos. 767-773; vol. 20, 1897, no. 1127; vol. 21, 1898, no. 1128; vol. 22, 1899, no. 1079; vol. 23, 1900, no. 1160; vol. 24, 1901, no. 1161; vol. 25, 1902, no. 1267.
- OLIVER, J. A. W.: Astronomy for amateurs. London, 1888. D, four copies, nos. 16-19.
- OLMSTED, D.: An introduction to astronomy. New York, 1870. O, no. 69.
- ORR, M. A.: Southern stars. London. sq. T, no. 781.
- OXFORD: Radcliffe Observatory: Observations: 1886, vol. 44, Q, no. 512; 1887, vol. 45, no. 574; 1888-1889, vol. 46, no. 689; vol. 47, no. 1059.
- : Catalogue of 6,424 stars for 1890. (STONE.) Oxford, 1894. Q, no. 621.
- : Meteorological observations. Oxford, 1901. Vol. 48, no. 1224.
- PAGE, W. M.: New light from old eclipses. St. Louis, 1890. D, no. 172.
- PALERMO: Real Osservatorio di: Pubblicazioni 1884-1888. Vol. 4, Q, no. 109.

- PARIS: Academie Royale des Sciences: Histoire de l'academie. Amsterdam, 1707-1763. s, 1699-1754, nos. 333-416.
- : Institut de France: Academie des Sciences: Bulletin du Comité International Permanent pour l'exécution photographique de la carte du ciel. Paris, 1895. Q, vol. 2, no. 1329.
- : L'observatoire. Paris, 1887, 1891, 1896. F, vols. 1-3, nos. 711-713.
- : Bureau des Longitudes: Annales. Paris, 1890. Q, vol. 4, no. 1065; Paris, 1897, vol. 5, no. 1074.—Annuaire. Paris, 1889, no. 94; 1890-1897, nos. 881-888; 1900-1902, nos. 1179-1181; 1898-1899, nos. 1106, 1107.—Connaissance des temps. Paris, 1890. O, no. 97; 1891-1899, nos. 957-965; 1900, no. 1040; 1901, no. 1051; 1902-1904, nos. 1248-1250.
- : L'observatoire d'astronomie physique: Annales. Paris, 1896. Vol. 1. Q, no. 573.
- : Société Française de Physique: Collection de Mémoires. Paris, 1884, 1885, 1887, 1889, 1891. Vols. 1-5, O, nos. 830-834.—Séances. Paris, O, 1889-1890, no. 1063; 1891-1892, no. 1064; 1897-1898, no. 1338; 1899-1900, no. 1339.
- : Conférence internationale des étoiles fondamentales de 1896. Paris. Q, no. 1334.
- PARKES, S. H.: Unfinished worlds. London, 1888. O, no. 270.
- PETER, BRUNO: Untersuchung des Vorüberganges der Venus vor der Sonnenscheibe im Jahre 1882. Dresden, 1877. F, no. 1330.
- PETERS, C. H. F.: Beitrag zu veränderlichen Sternen. Q, no. 742.
- PETIT, F.: Traité d'astronomie pour les gens du monde. Paris, 1866. D, no. 523.
- PHOTOGRAPHIC TIMES: New York. Q, vol. 28, 1896, no. 889; vol. 29, 1897, no. 765.
- PHYSICAL REVIEW: New York. Q, vol. 3, 1895-1896, no. 1125; vol. 4, 1897, no. 760; vols. 5-9, 1897-1899, nos. 1097-1101; vols. 10, 11, 1900, nos. 1188, 1189; vols. 12, 13, 1901, nos. 1190, 1191; vol. 14, 1902, no. 1264.

POLA: Veröffentlichungen des Hydrographischen Amtes der Kaiserlichen und Königlichen Kriegs Marine. Gruppe II, Jahrbuch der Meteorologischen Erdmagnetischen und Seismischen Beobachtungen. Pola. 1897-1902. F⁴, Neue Folge, vols. 1-6, nos. 1308-1313.

POPULAR ASTRONOMY: Northfield, 1894-1901. Q, vols. 1-4, nos. 681-684; vol. 5, no. 880; vol. 6, no. 1121; vol. 7, no. 1077; vols. 8, 9, nos. 1192, 1193.

POPULAR SCIENCE MONTHLY: New York, 1892-1893. O, vols. 41-43, nos. 1326-1328.

POOLE BROS.: (See *Colas, J. A.*)

PORRO, J.: Des appareils optiques pour l'astronomie et la photographie. Paris, 1858. O, no. 190.

PORTER, J. G.: (See *Cincinnati.*)

POTSDAM: Astrophysikalisches Observatorium: Publicationen. Q, vol. 1; Leipzig, 1879; no. 656.—Vol. 2; Potsdam, 1881; no. 657.—Vol. 3; Potsdam, 1883; no. 658.—Vol. 4, part 1; Potsdam, 1885; no. 659.—Vol. 4, part 2; Potsdam, 1889; no. 194.—Vol. 5; Potsdam, 1886; no. 660.—Vol. 6; Potsdam, 1889; no. 195.—Vol. 7, part 1; Potsdam, 1892; no. 661.—Vol. 7, part 2; Leipzig, 1895; no. 654.—Vol. 8; Potsdam, 1893; no. 577.—Vol. 9; Potsdam, 1894; no. 653.—Vol. 10; Leipzig, 1895; no. 655.—Vol. 11; Potsdam, 1898; no. 973.—Vol. 12; Potsdam, 1902; no. 1222.—Vol. 13; Potsdam, 1899; no. 1044.—Vol. 14; Potsdam, 1903; no. 1342. Publicationen: Photographische Himmelskarte, Catalog: Vol. 1; Potsdam, 1899; no. 1062.—Vol. 2; Potsdam, 1901; no. 1223.—Vol. 3; Potsdam, 1903; no. 1343.

PRAGUE: K. K. Sternwarte: Astronomische Beobachtungen. Prague. F, 1884, no. 418; 1885-1887, no. 419; 1888-1891, no. 578; 1901, no. 1225.

PRATT, O.: Key to the universe. Salt Lake City, 1879. O, no. 548.

PRITCHETT, H. S.: (See *St. Louis.*)

PROCTOR, R. A.: Other worlds than ours. New York, 1889. Three copies, O, nos. 1-3.

- PROCTOR, R. A.: Half-hours with the telescope. New York, 1889. Three copies. s, nos. 41-43.
- : The moon. London, 1886. d, no. 48.
- : Star atlas for students and observers. London, 1886. f, no. 92.
- PULCOVA: Zum 50-Jährigen Bestehen der Nicolai Hauptsternwarte. St. Petersburg, 1889. f, no. 561.
- RADAU, M. R.: Progrès récents de l'astronomie stellaire. Paris, 1876. No. 186.
- RALEIGH and RAMSAY: Argon, a new constituent of the atmosphere. (Smithsonian Contributions to Knowledge, no. 1033.) Washington, 1896. q, no. 1281.
- RAMSAY, W.: (See *Raleigh and Ramsay*.)
- RAYET, G.: (See *André et Rayet*.)
- REUBEUR-PASCHWITZ. E. VON: Das Horizontalpendel. Halle, 1892. f, no. 1320.
- RICHARDS, E. L.: Elementary treatise on navigation and nautical astronomy. New York, 1901. s, no. 1149.
- RIO DE JANEIRO: Observatoire: Méthode pour déterminer les heures des occultations d'étoiles par la lune. 1899. f, no. 1140.
- RITTER, E.: Détermination de l'orbite d'une comète ou d'une planète. Genève, 1851. q, no. 511.
- RHEES, W. J.: James Smithson and his bequest. Washington, 1880. o, no. 979.
- ROBERTS, I.: Photographs of stars, star-clusters, and nebulae. London. sq. f, no. 617.
- ROGERS, W. A.: (See *Leipzig*.) Astronomische Gesellschaft.
- RUNKLE, J. D.: New tables for determining the values of the coefficients in the perturbative function of planetary motion. Cambridge, 1855. q, no. 1273.
- RUSSELL, H. C.: Results of double-star measures. Sydney, 1891. o, no. 601.
- : Results of observations, 1879-1881. Sydney. 1893. o, no. 602.
- : Recent measures of double stars made at Sydney. q, no. 742.

- RUSSELL, H. C.: Results of meteorological observations in New South Wales during 1887. Sydney, 1889. o, no. 685.
- SÄDLER, H.: (See *Clark, L.*)
- ST. LOUIS: Academy of Science: Total eclipse of the sun, January 1, 1889. (PRITCHETT, H. S.) Cambridge, 1891. F, no. 509.
- SAMPSON, W. T.: Report of total solar eclipse, July 29, 1878. Q, no. 103; in "Solar Eclipses, 1858-1885."
- SAN FRANCISCO: Astronomical Society of the Pacific: Publications. San Francisco. o, vols. 1-5, 1889-1893, nos. 636-640; vol. 1, three copies, 1889, nos. 668-670; vol. 2, four copies, 1890, nos. 521, 671-673; vols. 6-9, 1894-1897, nos. 975-978; vol. 10, 1898, no. 1046; vol. 11, 1899, no. 1078; vols. 12, 13, 1900-1901, nos. 1202, 1203.
- : California Academy of Sciences: Occasional papers. San Francisco, o, vols. 1-4, 1890-1893, nos. 809-812.—Proceedings. San Francisco, o, vols. 1-4. 1889, 1891, 1893-1895; nos. 813-819.
- : Technical Society of the Pacific Coast: Transactions. San Francisco, 1884-1888. Parts 1-5, o, no. 243; part 6, no. 600.
- SAWYER, E. F.: Catalogue of the magnitudes of southern stars. Q, no. 752.
- SCHEINER, J.: Astronomical spectroscopy. Frost's Translation. Berlin, 1894. o, no. 604.
- : Die Photographie der Gestirne. Leipzig, 1897. o, no. 1288.
- : Atlas zu "Die Photographie der Gestirne." Leipzig, 1897. Q, no. 1247.
- SCHULTZ-STEINHEIL, C. A.: Definitive Bahnelemente des Cometen, 1840. Q, no. 762.
- SCHUR, WILHELM: Bestimmung der Masse des Planeten Jupiter aus Heliometer-Beobachtungen der Abstände seiner Satelliten. Halle, 1882. F, no. 1331.
- SECCHI, P. A.: Le soleil. Paris, 1875. 2 vols., Q, nos. 151, 152.
- : Le soleil; Atlas de la première partie. Paris, 1875. Q, no. 157.
- : Catalogo delle stelle. Paris, 1867. o, no. 192.

- SEE, T. J. J.: Stellar evolution. Vol. I. Lynn, 1896. F, no. 764.
- SEYDLER, A.: Bahnbestimmung des Cometen, 1890 I. Q, no. 762.
- SIDEREAL MESSENGER: Northfield. O, vol. 1, 1883, no. 877; vols. 2-6, 1883-1887, nos. 70-74; vol. 7, 1888, no. 305; vol. 8, 1889, no. 75; vol. 9, 1890, no. 610; vol. 10, 1891, no. 611. (Continued as Astronomy and Astrophysics.)
- SINOBAS, MANUEL RICOY: Libros del saber de astronomia. Madrid, 1864. F, 5 vols., nos. 324-328.
- SIRIUS: Zeitschrift für Populäre Astronomie. New series. Leipzig, O, 1874-1885, vols. 1-13, nos. 223-235; vol. 17, 1889, no. 677; vol. 21, 1893, no. 678; vol. 23, 1895, no. 679; vol. 25, 1897, no. 876; vol. 26, 1898, no. 1085.
- SMYTH, C. P.: Teneriffe; An astronomer's experiment. London, 1858. D, no. 317.
- : Micrometrical measures of gaseous spectra under high dispersion. Edinburgh, 1886. Q, no. 558.
- : Madeira Spectroscopic. Edinburgh, 1882. Q, no. 559.
- SMYTH, W. H.: A cycle of celestial objects. Oxford, 1881. O, no. 316.
- SPOERER, G.: Ueber die Periodicität der Sonnenflecken seit dem Jahre 1618. Halle, 1889. F, no. 1332.
- STOCKHOLM: Astromiska Iakttagelser och Undersökningar. Stockholm, 1876, 1885, 1888, 1891, 1896. O, vols. 1-5, nos. 1321-1325.
- STOCKWELL, J. N.: Secular variations of the elements of the orbits of the eight principal planets. Washington, 1872. Q, no. 1272.
- STONE, E. J.: (See *Oxford*.) Radcliffe Observatory.
- STERNECK, R. VON: Relative Schwerebestimmung durch Pendelbeobachtungen. Wien, 1895. Q, no. 667.
- STRASSBURG: Kaiserliche Universitäts-Sternwarte: Annalen. Karlsruhe, sq. F, vol. 1, 1896, no. 694; vol. 2, 1899, no. 1071.
- STRÖMGREN, E.: Berechnung der Bahn des Cometen, 1890 II. Q, no. 762.

STUBBS, J. W.: (See *Brinkley, J.*)

SUNDERLAND: West Hendon House Observatory: Publications. Sunderland. Q, no. I, 1891, no. 528; no. II, 1902, no. 1256.

SYDNEY: Observatory: Description of the star camera. Sydney, 1892. F, no. 473.

—: Photographs of the Milky Way and nebulae. Sydney, 1890. Q, no. 529.

—: Results of double-star measures. (RUSSELL.) Sydney, 1891. O, no. 601.

—: Results of observations, 1879-1881. (RUSSELL.) Sydney, 1893. O, no. 602.

TABLES: Tafel zur Berechnung des Logarithmen der Summe oder Differenz zweier Zahlen. O, no. 841.

TACUBAYA: Observatorio astronomico nacional: Anuario. Mexico. S, 1890, no. 95; 1891-1899, nos. 1108-1116; 1900-1903, nos. 1295-1298.

TACHKENT: Publications de l'observatoire astronomique et physique. Tachkent, 1899-1901. Q, vols. 1, 2, 3, no. 1303.

TEBAR, J. M.: Estudios cosmogonicos. New York, 1889. Q, no. 766.

TERBY, F.: Observations divers, de l'Academie Royale de Belgique. Brussels, 1889. Q, no. 113.

TERBY, M. F.: Mars and Jupiter. Brussels, 1886. Q, no. 90.

THOMPSON: Disks for determining heliographic longitude and latitude. Parts A-F. No. 737.

TODD, D. P.: A new astronomy. New York. S, no. 1152.

—: Photographs of the corona, January 1, 1889. (Smithsonian Contributions to Knowledge, no. 692.) Washington, 1889. F, no. 100.

—: Report of total solar eclipse, July 29, 1878. (In "Solar Eclipses 1858-1885.") Q, no. 103.

TOPEKA: Transactions Kansas Academy of Sciences. Topeka. O, vol. 12, 1890, no. 519; vol. 13, 1893, no. 603.

TORONTO: Astronomical and Physical Society: Transactions. Toronto. O, 1890-1895, no. 570; 1898, no. 1204.

- TOULOUSE: Annales de l'observatoire astronomique, magnétique et météorologique. Paris, 1899. Q, vols. 3, 4, nos. 1336, 1337.
- TROUVELOT, E. L.: The Trouvelot astronomical drawings manual. New York, 1882. Q, no. 649.
- UPTON, W.: Star atlas. Boston, 1896. F, no. 710.
- VALENTINER, W.: Handwörterbuch der Astronomie. Breslau and Leipzig, 1897-1902. O, vols. 1, 2, 3¹, 3², 4, nos. 1290-1294.
- VIENNA: K. K. Universitäts-Sternwarte (Währing): Annalen. Vienna. F, vols. 4-6, 1886-1888, no. 697; vols. 7-9, 1891-1893, no. 698; vols. 10-12, 1896, no. 699; vol. 13, 1898, no. 1286.
- : Argelandersche Zonen für 1850.0. Vienna, 1890. Q, no. 720.
- : Von Kuffner'sche Sternwarte: Publicationen. Vienna. F, vols. 3, 4, 1894-1896, nos. 738, 739; vol. 5, 1900, no. 1138.
- : Astronomische Arbeiten des K. K. Gradmessungsbureau. Vienna. Q, vols. 6, 7, 1894-1895, no. 1314; vol. 8, 1896, no. 1315; vols. 9, 10, 1897-1898, no. 1316.
- VOIRON, M.: Histoire de l'astronomie 1781-1811. Paris, 1811. Q, no. 150.
- WALKER, S. C.: Researches relative to the planet Neptune. Q, no. 1274.
- WALLIS, T. H.: Catalogue of the California state library. Sacramento, 1889. O, no. 81.
- WARREN, H. W.: Recreations in astronomy. New York, 1888. D, four copies, nos. 4-7.
- WASHINGTON: Pacific Coasters' Nautical Almanac. 1888-1889. Washington, 1887-1888. O, nos. 1048, 1049.
- : Nautical Almanac Office: American Ephemeris and Nautical Almanac. Washington. Q, 1857, no. 1226; 1859, 1860, nos. 1227, 1228; 1865, no. 1229; 1869, 1870, nos. 1230, 1231; 1871, no. 946; 1872-1881, nos. 1232-1241; 1880, no. 945; 1882, no. 1242; 1883, no. 1243; 1884, no.

WASHINGTON: Nautical Almanac Office (*continued*).

- 663; 1885, no. 1244; 1886, 1887, nos. 988, 989; 1888, no. 664; 1891, no. 538; 1892-1894, nos. 542-544; 1895, no. 633; 1896, no. 576; 1897, 1898, nos. 634, 635; 1899, no. 665; 1900, no. 898; 1901, no. 1043; 1902, no. 1052; 1903, no. 1307; 1904, no. 1246; 1905, no. 1245; 1906, no. 1260.
- : Nautical Almanac Office: Astronomical Papers for the American Ephemeris and Nautical Almanac. Washington. F, vol. 1, 1882, no. 205; vols. 2, 3, 1891, nos. 535, 536; vol. 4, 1890, no. 206; vols. 5, 6, 1895, 1898, nos. 687, 688; vols. 7, 8, 1898, nos. 1283, 1284.
- : Total eclipse of the sun, July 29, 1878. Q, no. 103. (In "Solar Eclipses 1858-1885.")
- : Signal service: Professional Papers No. 15. Washington, 1884. F, no. 210.
- : Smithsonian Institution: Contributions to Knowledge. 100 (GILLISS), no. 103; 199 (NEWCOMB), no. 1276; 262 (NEWCOMB), no. 1000; 280 (ALEXANDER), no. 1279; 281 (NEWCOMB), no. 1277; 691 (BIGELOW) and 692 (TODD), no. 100; 1033 (RALEIGH and RAMSAY), no. 1281. —Annual Report. Washington. O, 1869, no. 579; 1872, no. 980; 1873, no. 588; 1874, no. 981; 1880, no. 982; 1881, no. 983; 1882, no. 591; 1883, no. 984; 1885, no. 985; 1886, no. 986; 1888, no. 520; 1889, no. 537; 1890, no. 584; 1891, no. 593; 1892, no. 594; 1893, no. 987; 1894, no. 585; 1897, no. 1056; 1898, no. 1142; 1899, no. 1194; 1900, no. 1167.
- : Annual report of Board of Regents of U. S. National Museum. Washington. 1891. O, no. 569.
- : U. S. Civil Service Commission. Annual reports. Washington. O, Fourteenth report; July 1, 1896-June 30, 1897; no. 972.—Sixteenth report; no. 1143.—Seventeenth report; no. 1205.
- : U. S. Coast Survey: Reports of observations of total eclipse of the sun, August 7, 1869. (Appendix 8 to Report of 1869.) Washington. sq. Q, no. 103. (In "Solar Eclipses, 1858-1885.")
- : U. S. Geographical Surveys: Geographical report. Washington, 1889. sq. F, no. 207.

WASHINGTON: National Academy of Sciences. Memoirs. Eclipse expedition to Caroline Island, May, 1883. Washington. sq. F, no. 102.

—: U. S. Naval Observatory: Observations. Washington. F, 1851-1852, no. 219; 1863, no. 220; 1876 (part I, no. 196; part 2, no. 197); 1877-1883, nos. 198-204; 1884, no. 504; 1885, no. 505; 1886, no. 527; 1887, no. 562; 1888, no. 632; 1889, no. 627; 1890, no. 563.—Second Series; Washington; F, vol. I, 1900, no. 1219; vol. II, 1902, no. 1216; vol. III, 1903, no. 1340.—Appendix I, 1873, no. 104; Appendix III, 1875, no. 110; Appendix I, 1876, Appendix I, 1877, Appendix II, 1877, no. 105; Appendix III, 1876, no. 103; Appendix I, 1878, no. 106; Appendix I, 1881, no. 107; Appendix II, 1882, no. 103; Appendix III, 1883, no. 108; Appendix I, 1885, no. 507; Appendix II, 1885, no. 741; Appendix III, 1885, no. 508; Appendix I, 1886, two copies, nos. 306, 1344; Appendix I, 1888, no. 742; Appendix I, 1890, no. 564.—Meteorological Observations, 1883-1888; Washington, 1891; no. 1270.—Catalogue of stars observed at U. S. Naval Observatory, 1845-1847; Washington, 1889; F, no. 211.—Second catalogue of stars (EASTMAN); Washington, 1898; F, no. 1067.

WATSON, J. C.: Popular treatise on comets. Philadelphia, 1861. D, no. 258.

WEBB, T. W.: Celestial objects for common telescopes. London, 1881. D, four copies, nos. 8-11.

WEINEK, L.: Die Photographie in der Messenden Astronomie, insbesondere bei Venusvorübergängen. Halle, 1879. F, no. 1333.

WEISS, EDMUND: Argelandersche Zonen for 1850.0. Vienna, 1890. Q, no. 720.

WHEWELL, W.: Of the plurality of worlds. London, 1859. D, two copies, nos. 323, 332.

WIEN: (See *Vienna*.)

WILLIAMS, A. S.: Zenographical fragments. London, 1889. O, no. 251.

WILLIAMS, W. M.: The fuel of the sun. London, 1890. O, no. 269.

188 *Publications of the Astronomical Society, &c.*

- WINTERHALTER, A. G.: International Astrographic Congress. (Appendix I, Washington Observations, 1885.) Washington, 1889. No. 507.
- WISLICENUS, W. F.: Astronomischer Jahresbericht (1899). Vol. I. Berlin, 1900. o, no. 1287.
- WITKOVSKY, B.: Géodesie pratique. St. Petersburg, 1898. o, no. 874.
- WOODBURY, W. E.: The encyclopædic dictionary of photography. New York, 1896. q, no. 1306.
- YARNALL, M.: Catalogue of stars observed at the U. S. Naval Observatory, 1845-1877. Washington, 1889. f, no. 211.
- YERKES OBSERVATORY: Publications. Chicago, 1900. f, vol. I, no. 1118.
- YOUNG, C. A.: The elements of astronomy. Boston, 1890. d, five copies, nos. 29-33.
- : Text-book of general astronomy. Boston, 1888. o, four copies, nos. 76-78, 1039.
- : The sun. New York, 1888. d, no. 47.
- ZÜRICH: Publicationen der Sternwarte des Eidg. Polytechnikums. Vols. 1, 2, Zürich, 1897, 1899. No. 1176.

DUPLICATES.

The Library of the Astronomical Society of the Pacific contains a number of duplicates as listed below. The Society would be glad to exchange or sell these duplicates, and correspondence concerning them should be directed to the librarian, S. D. TOWNLEY, Ukiah, Cal.

BOUND VOLUMES.

Author.	Title.
BURRITT, E. H.	Geography of the heavens.
HOOGEWERFF, J. A.	Magnetic observations at the U. S. Naval Observatory. 1888-1889.
KIRKWOOD, D.	The Asteroids.
LOCKYER, J. N.	Star-gazing.
LOOMIS, E.	Elements of astronomy. An introduction to practical astronomy.
MATTISON, H.	Atlas to illustrate Burritt's geography of the heavens.
MITCHEL, O. M. . . .	The planetary and stellar worlds. Popular astronomy.
NEWCOMB, S.	Popular astronomy.
NOBLE, W.	Hours with a 3-inch telescope.
OLIVER, J. A. W. . .	Astronomy for amateurs.
PROCTOR, R. A. . . .	Other worlds than ours.
WARREN, H. W. . . .	Recreations in astronomy.
WEBB, T. W.	Celestial objects for common telescopes.
YOUNG, C. A.	The elements of astronomy. General astronomy.
Madison—Washburn Observatory Publications. Vols. 1, 2, 3, 4, 5.	
Monthly Notices Royal Astronomical Society. Vols. 45 and 46.	

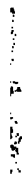
UNBOUND VOLUMES.

- Astronomy and Astrophysics. Vol. 11.
Astrophysical Journal. December, 1897.
Astronomische Mittheilungen. Nos. 81, 87.
Astronomical observations and researches. (DUNSK.) 8th part.
Astronomische Nachrichten. Nos. 2569, 2970, 3152. Reg. vol. 101.
Annals—Harvard College Observatory. Vol. 23, pt. 1; vol. 24, pt. 1; vol. 28, pts. 1, 2; vol. 44, pt. 1.
Conférence Internationale des Etoiles Fondamentales de 1896.
Contributions from Observatory of Columbia University. No. 15.
Journal of British Astronomical Association. Vol. 1, no. 1; vol. 7, no. 9.
Lick Observatory Bulletin. No. 2.
Monthly Notices of Royal Astronomical Society. May, June, 1889; March, 1890; sup. no., vol. 49, no. 9.
Observatory, The. December, 1885; January, March, April, October, 1888. Companion, 1888; May, 1889; January, September, 1891; September, 1892; January, 1893; December, 1896.
Popular Astronomy. January, 1900.
Publications of Chamberlin Observatory. No. 1.
Proceedings of California Academy of Sciences. 2d series; vol. 14, pt. 2.
REUBER-PASCHNITZ. Das Horizontalpendel.
RUNKLE, J. D. Tables—Coefficients. Perturbative Function of Planetary Motion.
Sidereal Messenger. May, 1885; February, 1888; March, May, June, August, October, November, December, 1889.
Transactions of Astronomical Observatory of Yale University. Vol. 1, pt. 5.

MISSING BOOKS.

The books enumerated in the list below have been missing from the library-room for some time. Members of the Society who have been accustomed to take books from the library are requested to look upon their shelves and see if any of them can be found.

Author.	Title.	No.
CHAMBERS, G. F.	Handbook of descriptive and practical astronomy. Vol. I.....	311
CLARK, LATIMER.	Manual of the transit instrument.....	304
CLERKE, AGNES..	History of astronomy during the nineteenth century	315
JOHNSON, S. J...	Eclipses, past and future	302
LEWIS, G. C.....	Historical survey of astronomy of the ancients	330
LOOMIS, E.....	Elements of astronomy	66
LYNN, WM.....	Celestial motions	301
NEWCOMB, S....	Popular astronomy	57
OLIVER, J. A. W.	Astronomy for amateurs	17
	Astronomy for amateurs	18
PROCTOR, R. A...	Other worlds than ours.....	3
	Myths and marvels of astronomy.....	489
SHELLEN, H....	Spectrum analysis	318
WEBB, T. W.....	Celestial objects for common telescopes	10
YOUNG, C. A....	Text-book of general astronomy.....	76
	Text-book of general astronomy.....	1039



CONTENTS.

	PAGE.
Townley, S. D. Catalogue of the Library of the Astronomical Society of the Pacific and of the Alexander Montgomery Library	157



PUBLICATIONS
OF THE
ASTRONOMICAL SOCIETY
OF THE PACIFIC.



VOLUME XVI.
NUMBER 98.
1904.

SAN FRANCISCO
PRINTED FOR THE SOCIETY

1904.

[Entered in Post Office at San Francisco, Cal., as second class mail matter.]

COMMITTEE ON PUBLICATION.

ROBERT G. ALEXN, Mt. Hamilton, Cal.

FRANK SCHLESGLER, Williams Bay, Wis.

SIDNEY D. TOWNLEY, Ukiah, Cal.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, OCTOBER 10, 1904. No. 98.

THE SUN'S VELOCITY IN SPACE.

By W. H. S. MONCK.

A mode of estimating the Sun's velocity in space relative to other stars, and thereby estimating its absolute velocity if that of the other stars can be obtained, has occurred to me which I think worth mentioning. I apply it only to the Sun's motion in Declination. That in Right Ascension could be computed on the same principle, but the computation would be somewhat more laborious, besides which I apprehend that as regards this motion there are some disturbing influences. The North Pole is situated in rather an unobtrusive quarter of the sky, and there is no great constellation within a moderate distance of it which might be expected to affect the motion of a large number of stars; therefore I think the average velocity of the stars measured in the direction of the North Pole is about the average velocity for a point selected at random in the sky. The Sun in like manner does not seem to be situated in a part of the sky to or from which stars may be expected to move with unusual velocity. The average velocity of the stars to or from the Sun is not likely to differ much from the average velocity towards a point selected at random in the sky or towards the North Pole, for the reasons already stated. Hence, if we can compare the Sun's velocity in the direction of the North Pole with the average motion of the stars (whether approaching or receding) in that direction, and also ascertain the average velocity of the stars in the line of sight, we may be able to estimate the actual velocity of the Sun's motion towards the North Pole in miles per second.

It is only the stars with considerable proper motion whose proper motions have been ascertained with accuracy or in whose

case we possess anything like a complete list of stars having a motion to or from the North Pole exceeding a definite limit. But if we take, suppose, the one hundred stars having greatest proper motion towards the North Pole and the one hundred stars having greatest proper motion away from it, may we not conclude that the difference between the observed proper motions is due to the motion of the Sun in this direction—the effects of this motion being additive in case of one set of one hundred stars and subtractive in that of the other? This is the principle which I mean to employ. In M. BOSSERT'S catalogue, which I think is the largest catalogue of stars with considerable proper motion that I have met with, I found three hundred and twenty-two stars whose annual motion towards the North Pole is not less than $0''.10$. Possibly this list is incomplete at the lower end, as all catalogues are apt to be; but from the number of stars contained in it which have a proper motion in declination of $-0''.10$, I think the omission cannot be very numerous. I then took from the same catalogue the three hundred and twenty-two stars which had the greatest proper motion away from the North Pole, and it is on the comparison of these two lists of three hundred and twenty-two stars that I propose to base my estimate of the Sun's velocity in that direction compared with that of an average star. I may, however, remark at the outset that the stars with which I am dealing are not average stars; they are selected on account of their large proper motion. Now, large proper motion may arise from the nearness of the star or from its motion being very nearly perpendicular to the line of sight; but it may also arise—and no doubt in some instances does so—from the star being moving through space with more than the average absolute motion. In this latter case, of course, the effect of the Sun's motion on that of the star will be proportionally less than if it had been moving with the average velocity. If its absolute motion in this direction be double the average velocity, the Sun's motion will only produce half the average proportional effect on it. With this preface I give the results for every tenth star in each series down to the one hundred and sixtieth, and for every twentieth star down to the three hundred and twentieth, beyond which point the catalogue in question does not enable me to proceed.

MOTION IN NORTH POLE DIRECTION.

No. of Star.	Reced- ing.	Approach- ing.	No. of Star.	Reced- ing.	Approach- ing.
10....1	.98	0".95	130....0	.48	0".23
20....1	.35	0 .76	140....0	.46	0 .22
30....1	.18	0 .61	150....0	.44	0 .21
40....1	.05	0 .45	160....0	.43	0 .20
50....0	.88	0 .39	180....0	.40	0 .18
60....0	.80	0 .36	200....0	.39	0 .16
70....0	.73	0 .34	220....0	.37	0 .15
80....0	.67	0 .30	240....0	.35	0 .13
90....0	.61	0 .29	260....0	.34	0 .12
100....0	.56	0 .26	280....0	.33	0 .11
110....0	.53	0 .25	300....0	.31	0 .10
120....0	.50	0 .24	320....0	.31	0 .10

In the early part of this table the proportion is a little over 2 to 1 (in two instances being slightly under that figure), and it is not until reaching about the two-hundredth star of each series that it gets up to $2\frac{1}{2}$ to 1, from which it continues to rise until it stands at a little over 3 to 1 at the end of the table, where the rise is apparently still in progress. I have already suggested two possible explanations of this fact: First, that the stars in the earlier part of the list (in both series) have on the average greater absolute proper motions, and that the effect of the Sun's motion on them is therefore proportionally less; and, secondly, that M. BOSSERT's catalogue, which I am using, is more deficient in its list of stars having proper motions of between 0".10 and 0".15 in North Pole direction, than in stars having proper motions of between 0".30 and 0".40. Both causes probably contribute to the result; but, bearing in mind that the increase of the ratio is evidently still in progress where my list terminates, I think that with a longer and more complete list of stars the proportion would not be likely to prove less than 3 to 1. A proportion of 2 to 1, it is hardly necessary to state, indicates that the Sun's motion in North Pole direction is one third of the average velocity of the stars resolved in that direction; while a ratio of 3 to 1 implies that the Sun's velocity in that direction is just one half of the average. The Sun is consequently either a slow-moving star or its motion is directed to a point

whose northerly declination falls considerably short of 45° . If we take the average velocity of the stars resolved in this direction (or in any direction assumed at random) to be ten miles per second, the Sun's velocity resolved in the direction of the North Pole will be five miles per second. But I suspect that the general average of star-velocity resolved in a particular direction (irrespective of sign) is greater than ten miles per second, especially as regards such stars as I have been considering.

Another mode of regarding the table suggests that the true proportion between the motions of receding and approaching stars in North Pole direction is at least 3 to 1. I mean, comparing the numbers attached to the approaching and receding stars which have approximately the same apparent proper motion. I have tried this for the receding stars numbered 30, 60, etc., on to 330, in my list, and give the numbers of the approaching stars which most nearly coincide, and also the proper motion of the approaching star whose number is one third of that considered.

No. of Receding Star.	Motion.	No. of Nearest Approaching Star.	Motion.	No. of Approaching Star, = $\frac{1}{3}$ of Receding.	Motion.
30...	1".18	7-8...	1".15	10...	0".95
60...	0.80	16...	0.80	20...	0.76
90...	0.61	30...	0.61	30...	0.61
120...	0.50	35...	0.49	40...	0.45
150...	0.44	41...	0.44	50...	0.39
180...	0.40	48-9...	0.40	60...	0.36
210...	0.38	51-5...	0.38	70...	0.34
240...	0.35	62-6...	0.35	80...	0.30
270...	0.33	71-2...	0.33	90...	0.29
300...	0.31	77-8...	0.31	100...	0.26
330...	0.30	79-82...	0.30	110...	0.25

Here there is in every instance more than three times as many stars with a given amount of receding motion as with the same amount of approaching motion, with a single exception in which the number is exactly threefold. Towards the end of the table the number becomes nearly 4 instead of 3. Now, a ratio of 4 to 1 would imply that the Sun's motion in North Pole direction was just the average motion of the stars

resolved in that direction. But the present test is not as fair a test as the preceding one. As *real* proper motion diminishes we may expect to find an increasing number of stars at every stage. Hence, the number of stars which can be *brought down* to a particular figure by the effect of the Sun's motion will probably be always less than those that can be *raised to* it by the same effect; and if we take all the stars having a given velocity (irrespective of sign) in the direction of the North Pole of, say, $0''.30$ per annum, our list will contain a larger number of raised stars than of lowered stars. I do not, therefore, see any valid reason for inferring that the Sun is moving towards the North Pole with a velocity exceeding one half of the average star-motion resolved in that direction. I hope some other member of the Society will take up the subject and arrive at more extensive and satisfactory results. I thought the method in any event worth mentioning, and, with our growing knowledge of the spectroscopic velocities of the stars, I think the prospect of being able to measure the Sun's motion in miles per second cannot be regarded as by any means hopeless.

STAR CATALOGUES.

BY ELLIOTT SMITH.

The determination of the positions of the stars has long been a matter of much concern to astronomers, and star catalogues have from time to time been issued giving their position with greater or less precision, according to the skill of the observer, the accuracy of his instruments, or the purpose for which the catalogue was made. As a result we have many star catalogues at our disposal, and it may not be out of place to call the attention of A. S. P. readers to a few of these at this time.

Without going into detail it will, no doubt, be sufficient merely to mention the earlier catalogues. They are so inaccurate as to be of no practical value, and they have no connection with modern catalogues, with the exception that the names or numbers assigned to the stars in some of them are in use

at the present day. HIPPARCHUS, PTOLEMY, AL-SUFI, and ULUGH BEIGH in order concerned themselves with star places; and the names of TYCHO BRAHE, HALLEY, and HEVELIUS are familiar to students of astronomical literature in this connection. All of the catalogues which they published, with the exception of that of HIPPARCHUS, which has not been preserved, have been compiled and published in the thirteenth volume of the Memoirs of the Royal Astronomical Society, with an introduction giving a description of each.

The middle of the seventeenth century marks the beginning of an epoch of unprecedented activity in the history of catalogue-making, and it may be said to have been formally inaugurated at the founding of the Greenwich Observatory in 1675. This new activity received its impulse from the direct necessity to navigators and explorers of a better knowledge of the positions of the stars and of the motion of the moon and planets.

It was possible for the navigator to determine his latitude at sea with accuracy sufficient for his purpose by simply observing the height of the Pole Star, but the problem of longitude at sea for many years baffled the most expert navigators, and mathematicians were not able to solve it. Handsome prizes were offered by nations whose conquests and colonies in the new world rendered their navigation important, and many methods were suggested. When finally the method of determining longitude by *lunar distances* was proposed, it was found that the knowledge of the positions of the stars and of the motion of the moon and planets was so inaccurate as to render the plan impracticable.

When this report was made to Charles II of England, he at once ordered that an observatory be founded to determine accurately the positions of the fixed stars and the motions of the moon and planets, and in other ways to assist navigation. Systematic observations of the positions of the stars thus begun at Greenwich are being continued by its observers at the present day. Other astronomers, inspired by this new incentive, have been active in meridian observations, so that in the past two centuries such a wealth of catalogues have accumulated that it would be manifestly impossible in so short an article as this to mention more than a small fraction of them. All we can hope to do is to call the attention of the reader to a few of the

catalogues found in an observatory library of to-day, of interest from the standpoint of history or of importance to the advancement of the science of astronomy.

The so-called British Catalogue, derived from the observations of FLAMSTEED, the first Astronomer Royal, was published in 1725 in the third volume of the *Historia Celestis*. It was revised and enlarged by BAILY in 1835, and as thus completed contains over 3,300 stars for the epoch 1690. In the column of the catalogue headed "Difference from Bradley" it is interesting to note that in Right Ascension a difference of five minutes of arc is not uncommon, and in Declination the difference in some cases is three minutes.

BRADLEY published no catalogues himself, but while at the Greenwich Observatory he made such accurate observations and such complete records of them that they have been of great value to the science of astronomy. MASON made a catalogue of 389 stars from BRADLEY's observations, whose places were published in the Nautical Almanac for 1773.

It was left to BESSEL, however, to do the first thorough work upon the observations made by BRADLEY. With the method of reduction which he himself had perfected BESSEL derived the positions of more than three thousand stars from the observations made by BRADLEY from 1750 to 1762. The epoch is 1755, and the catalogue was published in 1818 in BESSEL's *Fundamenta Astronomiæ*. This catalogue was of much importance to the science of astronomy at the time of its publication. By a comparison with the catalogues of BESSEL's own time the precession was more accurately determined and the proper motions of many stars became known, making it possible to predict their places for the future with accuracy.

Exact observations are of value at any time, but that their value increases as time goes by is well exemplified by the work of Dr. AUWERS upon the Bradley stars in the latter half of the nineteenth century. With all the refinements of reduction known to modern times and with corrections derived from a thorough investigation of the Bradley instruments, Dr. AUWERS re-reduced the whole mass of BRADLEY's observations made between 1750 and 1762. The epoch of the catalogue, as in BESSEL's, is 1755, and it contains 3,222 stars. A compari-

son of the Bradley positions, thus derived, with observations of the same stars made ninety years later furnished over three thousand proper motions. The work of Dr. ATWEARS upon the Bradley stars is published in three volumes: the first contains the determination of the constants of the instruments and the corresponding corrections: the second the results of observation in Right Ascension and zenith distance, and the third the star catalogue. The third volume was published in 1882, the second in 1888, and the first recently came from the publishers under date of 1903.

LACAILLE is the author of three catalogues of stars observed at the Cape of Good Hope. His work attracted considerable popular attention, for he was among the first astronomers to make an expedition to the southern hemisphere for the purpose of observing the southern sky. The first catalogue contains 398 stars for the epoch 1750: the second is a catalogue of 9,766 southern stars for the same epoch; and the third is of 515 zodiacal stars for 1765. The second catalogue was printed about the middle of the nineteenth century at the expense of the British association. The observations for the third catalogue were reduced by BAILY, but not so accurately as the state of the science warranted, and the catalogue has not been of as much service as it might have been.

MAYER'S catalogue of 998 zodiacal stars was published at Göttingen in 1775. It may be found in the fourth volume of the *Memoirs of the Royal Astronomical Society*. D'AGELET'S catalogue was intended to be a very comprehensive one. It was contemplated to determine the positions of all the stars of the northern hemisphere down to the ninth magnitude. As finally completed the catalogue contains 47,400 stars for the epoch 1800. The positions as given by this catalogue are not very exact, but it has been useful because of being so extensive. The thirty-six fundamental stars of MASKELENE, fifth Astronomer Royal, were probably the most accurately determined of any up to his time, and they were in general use as reference points by astronomers in the early part of the nineteenth century. It may be of interest to note here that MASKELENE was the first observer who, in taking a star's transit, divided the seconds into tenths. Observers previous to his time gave simply the nearest second.

The first catalogue of PIAZZI was published in 1803. It contained 7,648 stars, the thirty-six stars of MASKELENE being used as fundamental. Some doubt being thrown upon the Right Ascensions of the Maskelene stars, PIAZZI resolved to make a catalogue founded exclusively upon his own observations. He first constructed a preliminary standard catalogue of 120 stars, published in 1607, to be used as fundamental in the catalogue which followed. This catalogue of 7,646 stars was published in 1814, and at that time was considered of great importance. The observations and reductions were made by PIAZZI himself, and the refraction corrections were derived by him exclusively from his own observations.

All of the Piazzi stars were reobserved by TAYLOR of Madras for the epoch 1835. Most of the southern stars of PIAZZI may be found in the Cordoba General Catalogue for 1875, and the northern Piazzi stars are contained in the *Astronomische Gesellschaft* Catalogue for the same epoch. The reobservations of the Piazzi stars for 1900 completes the list of four epochs for those stars well distributed throughout the century, the southern stars having been observed by Professor TUCKER of the Lick Observatory, and the northern stars by Professor PORTER of the Cincinnati Observatory for the last epoch. A large number of the Piazzi stars have been included in special lists as zodiacal stars and many have been observed as fundamental. The original observations are being reduced anew by Dr. HERMAN S. DAVIS. As a result of all this there is a large amount of material outstanding in regard to the Piazzi stars, and it is expected that a discussion of it will yield results of no little interest and value to astronomy.

Professor AIRY, while Astronomer Royal at the Greenwich Observatory, derived the positions of 4,243 stars from the observations of STEPHEN GROOMBRIDGE for the epoch 1810. The resulting catalogue is of circumpolar stars, and has been of importance for that reason. Those astronomers who have taken up the task of forming a normal system or fundamental catalogue have had constant recourse to the Groombridge catalogue.

BESSEL has been mentioned in connection with the Bradley reductions, but BESSEL himself conducted a valuable and extensive series of observations at the Königsberg Observatory.

Between the years 1821 and 1833 he observed a large proportion of the stars down to the ninth magnitude, quite uniformly distributed in the zone -15° to $+45^{\circ}$ of Declination. The observations were reduced by Professor WEISSE, of Cracow, and published in two volumes at the expense of the St. Petersburg Academy of Science. The first volume contains the stars between -15° and $+15^{\circ}$ of Declination, and the second those between $+15^{\circ}$ and $+45^{\circ}$. The two volumes contain over 62,500 stars for the epoch 1825. ARGELANDER continued the observations according to BESSEL's plan from $+45^{\circ}$ to $+80^{\circ}$. OELTZEN reduced ARGELANDER's observations, and the resulting catalogue in two volumes gives the position of nearly 26,500 stars for the mean epoch 1842.

In connection with star catalogues, however, ARGELANDER will be longest remembered for his work upon the *Bonn Durchmusterung*. By an extensive series of observations he obtained the approximate positions of all the stars to magnitude 9 between $+90^{\circ}$ and -2° of Declination for the epoch 1855. The three volumes in which his work is published contain about 324,200 stars. SCHÖNFELD continued the *Durchmusterung* to Declination -23° . His results are published in one volume, which constitutes the fourth volume of the *Bonn Durchmusterung*. It contains nearly 133,700 stars for the common epoch 1855.

The work of observing the southern stars on the same plan from Declination -23° to the South Pole yet remained to be done, and the task was undertaken by the Cordoba Observatory. The actual northern boundary at which their work began was Declination -22° , so that there is a zone of one degree in common between the catalogues of SCHÖNFELD and Cordoba. SCHÖNFELD included all stars to the nine and one half magnitude in his catalogue, while the Cordoba *Durchmusterung* contains all the stars to magnitude 10 and many even fainter. So far three volumes containing the approximate positions of 489,600 stars between -22° and -52° have been published. The epoch is 1875. The work of cataloguing the remaining portion of the southern sky is still in progress at Cordoba. If it is as rich in stars as the portion already observed it is estimated that the Cordoba *Durchmusterung* completed will contain over 800,000 stars, making a total of considerably more

than a million and a quarter stars for the entire sky as catalogued in this great work.

The catalogue in two volumes known as the Gould zones properly represents the results first sought by the founder of the Cordoba Observatory. This catalogue contains the positions of 73,160 stars for 1875 between -23° and -80° of Declination. It includes stars to magnitude $9\frac{1}{2}$, and is in reality a continuation of observations in the southern hemisphere according to plans employed by BESSEL and ARGELANDER in the construction of their catalogues of the northern sky, described above. The observatory was organized by Doctor GOULD, as the National Observatory of the Argentine Republic, and it has been carrying on some extensive pieces of work, of which the *Durchmusterung* is an example.

While early in the nineteenth century the northern sky was receiving a great deal of attention, the southern sky was not wholly neglected. LACAILLE'S observations in the southern hemisphere have already been mentioned. The Rev. F. FAULOWS, astronomer at the Cape, published in volume CXIV of the *Philosophical Transactions* a catalogue of 273 south circumpolar stars for 1824. BRISBANE'S catalogue of 7,385 stars published in 1835; RÜMKE'S catalogue of some 12,000 stars for 1836; HENDERSON'S Declinations and Right Ascensions of 172 and 174 stars respectively for 1833; JOHNSON'S catalogue of 606 southern stars for 1830; TAYLOR'S general catalogue containing 11,000 stars for 1835, and his catalogue of 97 Principal Fixed Stars for 1845,—all these were among those most in use by astronomers interested in the accurate positions, and in the magnitudes and proper motions of southern stars up to the middle of the last century. Other later catalogues of southern stars that have been in general use and of recognized value to astronomy are the Argentine General Catalogue for 1875, containing all of the brighter stars of the sky within 100 degrees of the South Pole, the catalogue of 1,963 stars by GILLIS, MACLEAR'S catalogue of 1,159 stars for 1860, STONE'S catalogue of 78 south circumpolar stars and his catalogue of 12,441 stars for 1880.

For stars in the northern hemisphere there is such a wealth of observation that to enumerate the catalogues that are of value would require a small volume. We shall therefore men-

tion only a few of those which have been most used by astronomers. Perhaps the catalogues to which we should give our first attention are those which from time to time have been compiled from the Greenwich observations. The Greenwich Twelve-Year Catalogue of 2,156 stars is founded on observations made at Greenwich for the twelve years beginning in 1836. The first six years of observation were reduced to 1840, and the other six years to the epoch 1845. The Six-Year Catalogue of 1,576 stars for 1850, the Seven-Year Catalogue of 2,022 stars for 1860, the new Seven-Year Catalogue of 2,760 stars for 1864, the Nine-Year Catalogue of 2,263 stars for 1872, the Ten-Year Catalogue of 4,059 stars for 1880, the Five-Year Catalogue of 258 fundamental stars for 1890, and a new Ten-Year Catalogue for the same epoch, are monuments to the industry, accuracy, and skill of the Greenwich observers.

In point of accuracy and uniformity in reduction the Pulkova catalogues have not been surpassed. The epoch of their first catalogue is 1845, the Right Ascensions and Declinations being published in separate volumes. The number of stars contained is about 375. Four other catalogues whose epochs are separated by ten-year intervals have been much used. The Pulkova catalogue for 1855 has 3,542 stars; the catalogue for 1865 is published in volume XII of the Pulkova Observations. H. ROMBERG derived a catalogue of 5,634 stars from the Pulkova observations for 1875, and NYREN'S Standard Catalogue of Declinations comes from the same source.

What Greenwich and Pulkova have been to the northern hemisphere, the observatory at the Cape of Good Hope has been to the southern. An enumeration of the epochs of the catalogues which have been published at the Cape will give an idea of the activity of that observatory in catalogue making. 1833, 1840, 1850, 1860, 1880, 1885, and 1890 are epochs of catalogues which have been compiled and published from the Cape Observatory.

Other observatories which may be mentioned as having been especially active in meridian observations are Munich, Oxford, Melbourne, Harvard College, Albany, Washington, Cincinnati, Madison, Berlin, and Paris.

The *Astronomische Gesellschaft* Catalogue is one of the most important of recent date. It will contain, when completed, all

the stars to the ninth magnitude included between $+80^\circ$ and -23° Declination. For observation the sky was divided into zones of five and ten degrees, different observatories becoming responsible for a larger or smaller zone according to their facilities for carrying on the work of observing. The object in each case was to have the zone assigned to any one observatory as near its zenith as possible to avoid errors in applying refraction corrections. The epoch is 1875 for the northern catalogues, 1900 for the southern.

The catalogue for the northern sky between -2° and $+80^\circ$ is all but complete. The second volume containing stars between $+70^\circ$ and $+75^\circ$ has not yet been published. It may be of interest to note that two observatories of the United States—Albany and Harvard College—took part in this great work. The first volume of the catalogue for the southern zone recently arrived at the Lick Observatory, and it is hoped that the date of completion of the others may not be far distant.

NEWCOMB and AUWERS are authors of fundamental catalogues most in use at the present time. PORTER and BOSSERT have published standard catalogues of proper motion stars.

The discussion and comparison of star catalogues has become a recognized field of labor for astronomers, and results of no little importance have been derived from it. BOSS, NEWCOMB, AUWERS, CHANDLER and others have concerned themselves in this line of work.

At one time the making of star catalogues was considered the most important branch of astronomy. Researches in the line of what we understand as physical astronomy were looked upon with very little sympathy by the old-line astronomers. We would say in conclusion, however, that the remarkable development which the so-called physical astronomy has undergone in the last half century has only enhanced the importance to the science of an exact knowledge of the positions of the stars, and at present catalogues are being made which aim to give the positions of stars with still greater accuracy. Older catalogues give a clue to the proper motions, so that even though we have a large and ever increasing number of catalogues they are all of use in advancing our knowledge of the sky.

THE LOSS OF LIGHT BY ABSORPTION AND REFLECTION IN THE 36-INCH OBJECTIVE.

By J. H. MOORE.

The visual objective of the 36-inch refractor of the Lick Observatory consists of two lenses, a brief description of which, as furnished by Alvan Clark & Sons, is as follows:—

Radii of Curvature.*				Thickness.	
				Center.	Edge.
		Inches.	Inches.	Inches.	Inches.
Crown No. 1734	$R_1 = +259.52$	$R_2 = +259.52$		1.96	0.60
Flint No. 1588 ..	$R_3 = -239.59$	$R_4 = -40000.$		0.93	1.65

It will be seen that the total thickness of glass is about three inches. Now, from the table given by Professor VOGEL,† for the loss of light in lenses of different thickness, we find that the loss for the visual rays in the 36-inch objective is about twenty-seven per cent and for the photographic rays forty per cent.

In spectrographic work a thin double-concave lens (2.5 inches aperture) is placed one meter within the visual focus to correct for chromatic aberration in the region $\lambda 4500$. The loss at this lens is estimated to be about ten or fifteen per cent. The present determination is for the loss of light in the region $\lambda 4500$, due to the combined objective and correcting lens.

The Mills spectrograph, mounted upon the large telescope, was directed toward the region of sky 87° North Declination (S. P.) and zero hour-angle, and a spectrogram taken with a slit-width .005 inch and one hundred seconds exposure. The spectrograph, removed from the telescope, was pointed to the same region and with the above slit-width exposures were given ranging from thirty to sixty seconds. A little consideration will show (since the angular aperture of the collimator is equal to that of the 36-inch objective), that the exposure when the spectrograph is off the telescope, which gives the same image density as one hundred seconds exposure when

* *Publications of the Lick Observatory*, Vol. III.

† *Astrophysical Journal*, Vol. V, 1897.

it is on the telescope, represents the percentage of light transmitted by the objective and correcting lens.

To eliminate any error due to variation in the intensity of the sky-light with changing hour-angle of the Sun, the exposures were made in this way: One on telescope, three off telescope; one on telescope, three off telescope; one on telescope.

The effect of diffraction at the slit is to allow light outside the cone of aperture equal to that of the objective to fall upon the collimator-lens when the spectrograph is off the telescope. Any error due to this was shown, by another series of experiments in which a slit of .0006 inch was used, to be very small. In the present experiments the effect of diffraction at the slit is negligible, as a relatively wide slit was employed.

It was possible to detect a two per cent variation in the intensity of the photographic images. From the mean of ten plates an exposure of fifty-one seconds with the spectrograph off the telescope was found to give the same image density as one-hundred-seconds exposure with spectrograph on the telescope. The loss by absorption and reflection of rays $\lambda 4500$ at the 36-inch objective and correcting-lens is then forty-nine per cent. Assuming the loss at the correcting-lens to be about ten per cent, this value agrees very well with that calculated above for the 36-inch lens.

Lick Observatory.

THE LOSS OF LIGHT BY DIFFRACTION AT A NARROW SLIT.

BY J. H. MOORE.

In the design of astronomical slit-spectrographs, where the source of light is in general faint, the question of utilizing as much of the light as possible becomes of fundamental importance. The particular problem for which the instrument is intended will require a certain resolving power and dispersion, which in a prism-spectrograph will correspond to a definite and unavoidable loss of light by absorption and reflection at the prisms and lenses.

To obtain the required purity of spectrum it is necessary

to use a slit of small aperture, at which an additional loss occurs, due (1) to the diminished area of the image source, and (2) to diffraction at a narrow slit. This loss at the slit depends upon the linear slit width, while the purity of the spectrum depends only upon the angular aperture of the slit, as seen from the center of the collimator-lens. It is evidently possible, then, to preserve the purity and at the same time avoid some of the loss at the slit, by employing a collimator of sufficient focal length and aperture, and a slit of greater linear width. The importance of this principle in the design of astronomical spectrographs was first pointed out by Professor CAMPBELL.*

The loss of light by diffraction at a narrow slit, for the region of spectrum $\lambda = 1.8\mu$ and for slit-widths from 0 to 0.5mm , has been investigated by Professor ARBOT† in his bolometric researches in the infra red spectrum of the Sun. For the region of spectrum and slit-widths employed in line of sight-work no data are available for the loss by diffraction at the slit, and with a view to supplying these the present investigation was undertaken.

In spectrographic work we are interested in photographic intensities. A photographic method of comparing relative intensities from slits of different apertures was therefore selected. The spectrum of a constant source of light was photographed, using a slit-width .002 inch and thirty seconds exposure. This was taken as giving a standard image density. To obtain the relative intensity due to any other slit-width, say .001 inch, a graduated series of exposures was given with this width of slit. An exposure of sixty-six seconds for a slit .001 inch gives the same image density as that of our standard. The photographic intensity due to a slit .001 inch is taken as being proportional to thirty-sixths the photographic intensity due to a slit .002 inch. Any slight error due to the assumption that the density of a photographic image is proportional to the product of the exposure-time and intensity of the incident light is not effective in the present experiments.

The Mills spectrograph, mounted upon the 36-inch refractor, was directed toward the region of the sky 90° North

* W. W. CAMPBELL, The Mills Spectrograph of the Lick Observatory. *Astrophysical Journal*, Vol. VIII, 1898.

† Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. I, 1900

Declination and hour-angle six hours away from that of the Sun. The telescope was driven by the clock in order to eliminate the effect of the variation of the plane of polarization of sky-light with reference to the plane of the instrument. In this way a source of light was obtained which was found to be fairly constant when the hour-angle of the Sun was not greater than one hour. To guard against the effect of any variation in the sky-light, the exposures were made in this way (say for a slit .001 inch),—slit .002 inch 30 seconds exposure; slit .001 inch and 63, 64, and 65 seconds exposure, respectively; slit .002 inch and 30 seconds exposure; slit .001 inch and 66, 67, and 68 seconds exposure; slit .002 inch and 30 seconds exposure. It is possible to detect a five per cent variation in the image density by such a method of comparison.

In the following table are given the exposures from the mean of five plates for different slit-widths required to produce the same image density as that from a slit .002 inch and 30 seconds exposure, for the region $\lambda 4500$ (the center of the Mills spectrogram). The last column gives the percentage of loss by diffraction for slits of different aperture on the assumption that no light is lost by diffraction at a slit of .004 inch and that the exposure-time varies inversely at the slit-width.

Slit-Width in .001 Inch.	Time of Exposure in Seconds.	Percentage Loss by Diffraction.
4.0	13.0	00
3.5	15.0	00
3.0	17.5	4
2.5	22.0	8
2.0	30.0	13
1.8	34.5	15
1.5	42.5	18
1.4	45.0	19
1.3	49.5	20
1.2	55.0	22
1.0	66.0	24
0.9	77.0	25
0.8	86.5	26
0.7	103.0	28
0.6	134.0	35
0.5	172.0	40

From the above it will be seen that the loss by diffraction increases very rapidly for slits of linear aperture less than

.0007 inch. On the assumption that the light incident upon the slit is parallel, it can be shown that for a slit-width .0007 inch the width of the principal maximum of the diffraction pattern is equal to the diameter of the collimator-lens, (the constants of which in the Mills spectrograph are, focal length = 722.4^{mm} , effective aperture = 38^{mm}). A further decrease in slit-width will throw part of the principal maximum off of the collimator-lens, causing a rapid decrease in the intensity of the light.

A comparison of ABBOT's results with those given above will show his values for the loss by diffraction at a narrow slit to be relatively much greater than the ones obtained in the present experiments. A little consideration, however, will indicate the cause of this discrepancy (aside from the fact that the wave-length employed by him is four times that used in the present work) is due to the difference in the angular aperture of the collimator in the two instruments. ABBOT used a collimator of angular aperture of about one fifth that of the Mills spectrograph. We should therefore expect the loss by diffraction in his experiments to be relatively much greater than that obtained here.

With the Mills spectrograph, in line of sight-work, a slit of linear aperture .0013 inch is found to give sufficient purity. Now a collimator-lens of twice the diameter and focal length of the present one (neglecting the increased absorption of such a lens) would theoretically enable us to utilize about 2.3 times as much light, as we should then be able to double the slit-width.

On the other hand, the corresponding effective diameter of the collimator-lens would be about three inches. It is very doubtful whether it is advisable to use larger prisms than are employed in the present instrument, for several reasons. To mention only one, such prisms by their greater absorption would reduce greatly the increase of light gained in the above manner.

The substitution of a reflection grating for the prisms may be possible, but here we encounter the difficulty of mounting a reflection-grating so that it cannot move and at the same time not be cramped. Also, since for a reflection-grating there is no position of minimum deviation, a displacement of the

grating produces a corresponding shift in the lines of the spectrum.

We may use a Cassegrainian reflector of great relative focal length and a collimator-lens of small linear aperture. However, for average seeing the image would be larger for the instrument of greater focal length, and while we should gain some light, the gain would not be proportionate.

The telescope and spectroscope of greatest efficiency will be those in which the best compromise is made between the various opposing factors; and this will depend to a considerable extent upon the class of work for which the instrument is intended.

Lick Observatory. _____

VARIABLE STAR NOTES.

BY ROSE O'HALLORAN.

V Cassiopeiæ.

When first discovered in December, 1893, by Dr. ANDERSON, of Edinburgh, *V Cassiopeiæ* was supposed to be a temporary star, but further observation showed that it ranged from about seventh to twelfth magnitude in a period of 229 days. Though in a field thickly strewn with small stars, it may be found without circles by means of two stars of sixth magnitude with which it forms an obtuse triangle. These are numbered 1 and 2 in FLAMSTEED'S catalogue, the variable being about half a degree northeast of the latter, or in R. A. $23^{\text{h}} 7^{\text{m}} 22^{\text{s}}$, Decl. $+ 59^{\circ} 8' 4''$. Near the date of predicted maximum, August 15th, it was observed as follows:—

1904.

July 10. Brighter than any of the closely adjacent stars.

Equal to *c*.

July 15 and 17. Equal to *d*, less than *b*.

July 30. Brighter than *b*.

July 31. Ditto. Night very clear.

August 1 and 11. Brighter than *a*, which is the brightest of the numerous stars about one third of a degree to the northeast. *V* seems fully of 7.5 magnitude, but is less than star of 6.8 magnitude to the west.

- August 29. Less than *a*, brighter than *b*.
 September 2. Ditto.
 September 6. Less than *b*, equal to *d*.
 September 12. Less than *d*, equal to *e*.
 September 18. Equal to *e*. Moonlight.

U Cassiopeia.

This variable changes from eighth to fifteenth magnitude in 276 days. The following observations, taken during the last two years, accord with intermediate stages of predicted maxima and minima:—

1902.

- September 24. Brighter than the faint star about one minute of an arc north of it. In the accompanying chart it is below it and marked *g*.
 October 23. Brighter than *e*, less than *d*.
 October 28. Equal to *d*.
 October 31. Brighter than *d*, less than *c*.
 November 3. Ditto.

1903.

- August 16, 23, and 29. Brighter than *e*, less than *d*.
 September 2, 8, 13, and 14. About two-tenths magnitude less than *c*.
 September 16. Decreased, but still brighter than *d*.
 September 29. Brighter than *e*, less than *a*, equals *d*.
 October 12. Dimmer than *e*, brighter than *g*.
 October 25. Less than *g*.
 November 6. Invisible.

1904.

- July 12. Brighter than *d*, less than *c*.
 July 15. Ditto.
 July 31. Equals *f*, less than *e*, brighter than *g*.
 August 1. Less than *f*, brighter than *g*.
 August 11. Equals *g*.
 September 6, 12, and 18. Invisible.

This variable is in the vicinity of *Omicron* in *Cassiopeia*. In the charts, the comparison stars are named alphabetically, according to magnitude.

Proximity of U Lacertoides *N.* *Proximity of U Lacertoides*



W. Aurigæ.

Occasional observations of this star were taken as follows: 1904—January 4, 12, and 21, February 5. Invisible.

The maximum was predicted for August 15th, but cloudiness delayed observation until the 20th, when it was invisible, though *k* and *l* of 11 and 11.5 magnitude were distinctly seen. The morning was clear and a high power was used. On September 8th it was also invisible, though *k* was discernible in a hazy atmosphere.

X. Aquilæ.

As the minimum of *X. Aquilæ* was due on July 21, 1904, its vicinity was observed with a four-inch telescope, in which stars of twelfth magnitude are discernible in very clear weather. Seventeen observations were taken from the 11th of June to the 12th of September, but it was invisible. Several of the evenings were very clear. It may have decreased below twelfth magnitude.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter, Sept. 2, 6 ^h 58 ^m P.M.	Last Quarter, Oct. 2, 5 ^h 52 ^m A.M.
New Moon, " 9, 12 43 P.M.	New Moon, " 8, 9 25 P.M.
First Quarter, " 16, 7 13 A.M.	First Quarter, " 15, 9 54 P.M.
Full Moon, " 24, 9 50 A.M.	Full Moon, " 24, 2 56 A.M.
	Last Quarter, " 31, 3 13 P.M.

The autumnal equinox, the time when the Sun crosses the Equator from north to south, occurs September 23d, 4 A.M., Pacific time.

The second of the two eclipses of the year occurred September 9th. It was a total eclipse of the Sun, but it was not visible from any part of the United States. The line of totality ran across the Pacific from a position eastward of the Caroline Islands to the western coast of South America. Unfortunately there are practically no good observing stations along the line as seen on ordinary maps. This is doubly

unfortunate as the duration of totality is a long one, 6^m 24^s, and this would give an unusually good opportunity for observations of the outer portions of the corona, while the brighter inner parts are behind the Moon's disc, more than in an eclipse of shorter duration. the apparent disc of the Moon being larger than that of the Sun by an amount unusual at a time of eclipse. The duration of totality was about the same for the eclipse of May 17, 1901, but the average duration in total solar eclipses is only about half as great.

Mercury on September 1st is an evening star, setting about half an hour after sunset. It rapidly nears the Sun and passes inferior conjunction on September 15th. From that time until the last night in October it is a morning star. It reaches greatest west elongation, 17° 54', on October 1st, and then rises an hour and a half before sunrise. Until the middle of October the interval is an hour or more. The period is therefore a good one for seeing the planet as a morning star. The planet will be quite near the Moon on the evening of October 7th.

Venus is now an evening star, and has moved far enough away from the Sun to be seen in the evening twilight soon after sunset. It sets about forty minutes after the Sun on September 1st, an hour on October 1st, and an hour and a half on November 1st. It passes about 3° north of *Spica*, α *Virginis* on September 23d. There is a close approach to the Moon on the evening of September 10th, the day after New Moon.

Mars is a morning star, slowly falling behind the Sun in their common eastward motion. It rises a little after 3 A.M. on September 1st, and at a little after 2 A.M. on October 31st. It moves 36° eastward and 13° southward from *Cancer* into *Leo*, and on September 28th passes about 1° north of *Regulus*, α *Leonis*. Its actual distance from the Earth has begun to diminish, and there is a consequent increase in brightness. but it does not amount to much as yet. However, there will be no difficulty in seeing it, as it will be brighter than a second-magnitude star.

Jupiter rises at 8:40 P.M. on September 1st, at 6:36 on October 1st, and at 4:20 on November 1st. It reaches opposition with the Sun on the afternoon of October 18th. It moves about 6° westward and nearly 3° southward in the

constellation *Pisces*. There are few bright stars in that region of the sky. The late autumn and early winter evenings will give a fine opportunity for observations of this planet.

Saturn is also in good position for evening observation. It is on the southern meridian at 10:33 P.M. on September 1st, and at 6:27 P.M. on November 1st, and sets about five hours later than its time of meridian passage. It moves westward about 2° in the eastern part of *Capricorn* until October 19th, and then begins to move slowly eastward.

Uranus is in the southwestern sky in the evening. It is on the meridian at 7 P.M. on September 1st, and at 3:06 P.M. on November 1st, and sets about four and one half hours later. On account of its faintness it cannot be seen with the naked eye except when it is at a considerable distance from the horizon. It is stationary on September 4th, and then begins to move slowly eastward, moving about $1^\circ 30'$ up to the end of October. It is west and a little north of the group known as "the milk dipper," in *Sagittarius*, but no bright stars are very near.

Neptune is in *Gemini*. Toward the end of October it rises about 9 P.M.

During the early morning of October 27th the Moon will pass over the *Hyades* group in *Taurus*, and a number of the brighter stars will be occulted.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1904.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon, Nov. 7, 7 ^h 37 ^m A.M.	New Moon, Dec. 6, 7 ^h 46 ^m P.M.
First Quarter, " 14, 4 35 P.M.	First Quarter, " 14, 2 7 P.M.
Full Moon, " 22, 7 12 P.M.	Full Moon, " 22, 10 1 A.M.
Last Quarter, " 29, 11 38 P.M.	Last Quarter, " 29, 7 46 A.M.

The Sun reaches the winter solstice and winter begins December 21st, 10 P.M., Pacific time.

The Earth is in perihelion December 31st, 9 P.M., Pacific time.

Mercury passes superior conjunction with the Sun on the morning of October 31st, and remains an evening star until the morning of December 31st. It reaches its greatest eastern elongation, $20^{\circ} 30'$, on the morning of December 13th, and then sets at a little less than an hour and a half after sunset. For a week or more before and after that date it may be seen in the evening twilight; but the duration of its visibility is not as great as it is when the greatest eastern elongation comes in the spring months. Early in December, before it comes to greatest elongation, it will be in the most southern part of its orbit. This will cause the interval between sunset and the setting of the planet to be smaller than usual, and retard the time of its becoming visible. Also the interval between greatest elongation and inferior conjunction is only seventeen days. The corresponding interval for the preceding period was ten days longer. In December the planet is in the part of its orbit nearest the Sun, passing perihelion only a few days before coming to conjunction, and consequently it moves much faster.

Venus is also an evening star, and the interval between the setting of the Sun and of the planet increases rapidly. On November 1st it is about an hour and a half, on December 31st it is nearly three hours and a half, and the planet is nearly out to its greatest eastern elongation. The reason for the comparatively rapid increase now, as compared with the slow increase of interval for some months after superior conjunction, is this—up to about December 1st the planet was south of the Sun; after that date it begins to be more and more north of the Sun. This causes the rapid increase in interval from sunset to the setting of the planet. The eastward motion of the planet among the stars has been comparatively uniform. On November 16th, 10 P.M., it passes $1^{\circ} 28'$ south of *Uranus*, and on the morning of December 28th it is $0^{\circ} 48'$ south of *Saturn*. At the beginning of November it is about 4° north of *Antares*, α *Scorpii*.

Mars is drawing farther away from the Sun and rising earlier; on November 1st it rises at 2:21 A.M. and on December 31st at 1:16 A.M. It moves about 32° eastward and 13° southward from *Leo* into *Virgo*. On December 27th it is 4° north of *Spica*, α *Virginis*. On the morning of December 2d

there is a very close approach to the Moon, and an occultation in some places. On November 25th the planet reaches its greatest distance in miles from the Sun, although it is now nearer the earth by a considerable amount than it was at the time of its greatest distance, early in July. In consequence of the diminished distance from the Earth, more than counterbalancing the increase of distance from the Sun, *Mars* at the end of December will be about two and one third times as bright as it was on July 1st. This is an increase of almost exactly one magnitude, and at the end of the year it will be about as bright as a first-magnitude star like *Spica*.

Jupiter is in fine position for evening observation. It passed opposition with the Sun on October 18th, and is now well above the horizon at sunset. It crosses the meridian at 10:46 P.M. on November 1st, and at 6:39 P.M. on December 31st. It sets rather more than six hours after meridian transit. Until about the middle of December the planet is moving westward in the constellation *Pisces*. It then begins to move eastward; but the whole motion during the two months is less than 3° .

Saturn is still in good position for observation in the western sky in the evening, although it draws rather close to the Sun toward the end of the year. It sets at 11:26 P.M. on November 1st and at 7:50 P.M. on December 31st, crossing the meridian about five hours earlier. It is in the eastern part of *Capricorn* and moves about 4° eastward during the two months.

Uranus is too near the Sun to be seen. It is in conjunction on December 22d, and changes from an evening to a morning star. It is still in *Sagittarius* and moves about 4° eastward.

Neptune is in opposition with the Sun on the evening of December 28th.

The first-magnitude star *Aldebaran*, α *Tauri*, will be occulted by the Moon on the evening of December 20th. The occultation will be visible from most parts of the United States.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

THE DOUBLE STAR O Σ 21.

In July of the present year I found that the 6.3-magnitude star, $6\frac{1}{2}^m$ preceding ϕ *Andromedæ* and $7'$ north of it, is a close double star. Measures on four nights give the following result:—

1904.54 $361^\circ.0$ $0''.22$ 6.2-8.0 magnitudes.

In view of the past history of this star, this discovery is both interesting and surprising.

It was first noted as a double star by OTTO STRUVE in 1845, and was measured by him on four nights, between 1845 and 1851, with accordant results, the mean of which is: $170^\circ.6$ $0''.56$ 6.9-8.2 magnitudes. This pair is known as O Σ 21, and was measured in 1884 by both SEABROKE and SMITH with results in fair agreement with STRUVE'S; and again on one night in 1898 by HUSSEY, who obtained $160^\circ.7$ and $0''.74$.

If this were the complete micrometric history of the star it would be very interesting, because of the great change apparently observed between 1898 and 1904; but in view of the meagerness of the observations there would be nothing very surprising about it.

But from the account given by Professor HUSSEY in his "Observations of the Pulkowa Double Stars" (*Lick Observatory Publications*, vol. V, p. 39), it appears that DEMBOWSKI could not measure this pair in 1864, 1865 or 1878; that MÄDLER, in 1845, measured a seventh-magnitude star a little preceding this star, obtaining $45^\circ.1$ $0''.97$, and supposed he was measuring O Σ 21; that BURNHAM measured MÄDLER'S pair in 1878, 1879, and 1891, and expressly stated that in the two former years he could not find any other pair in that vicinity; and finally, that

* Lick Astronomical Department of the University of California.

HUSSEY himself was unable to see O Σ 21 double on many nights in 1898 and 1900 (also in 1902. see *L. O. Bulletin*, No. 40), even with the 36-inch telescope. As Professor HUSSEY points out, it seems impossible to reconcile his positive measure with the subsequent negative results, and equally difficult to explain the agreement of his measure with OTTO STRUVE'S if some other pair was observed by either by mistake.

My measures only add to the puzzle, for it does not seem possible that the new companion can be identical either with the one measured by OTTO STRUVE or with the one seen by Professor HUSSEY. The explanation must be left to the future.

September 2, 1904.

R. G. AITKEN.

UNSUCCESSFUL SEARCH FOR PERIODIC COMETS.

It is generally best to keep silent about searches of any kind that result unsuccessfully, but occasionally it happens that failure has a value only second to success. This seems to apply with special force to the search for periodic comets whose orbits are supposed to be well known, and whose position in the sky, according to the predicted motion, is favorable for observation. I therefore wish to place on record the fact that I have looked for every periodic comet predicted to return to the neighborhood of the earth during the past two years, using the 36-inch telescope under the best obtainable conditions. With the exception of BROOKS'S comet, 1889 V, 1896 VI, which was found close to its predicted place on the first night's search, none of the comets looked for have been seen. Some, like PERRINE'S comet last year, and TEMPLE'S comet (1873 II) this year were so nearly in line with the Sun that their position could hardly be regarded as favorable. Others, like GIACOBINI'S comet last year and WOLF'S comet the present year, were not far from opposition at the time of search, and the failure to see them must be due either to the extreme faintness of the objects or to the uncertainty of the predicted positions. It is not feasible with a telescope as large as the 36-inch to examine a very large sky area for a faint comet. My practice has been to chart the predicted position of the comet and to examine minutely with a low-power eye-piece about a square degree of the sky about this position; then, more rapidly, several more square degrees along the line of predicted motion.

R. G. AITKEN.

September 5, 1904.

ONE HUNDRED AND FIFTY-FIVE NEW DOUBLE STARS.

Lick Observatory Bulletin, No. 61, contains detailed measures of one hundred and fifty-five new double stars, numbered, in continuation of those previously published, A 646 to A 800.

More than one half of these pairs were discovered with the 12-inch telescope, but nearly all of the measures were made with the 36-inch.

Only two pairs whose components are separated by more than 5" are included in this list, 116 pairs, or 75 per cent of the whole number, are separated by less than 2", and 13 pairs are closer than 0".25. The list includes two naked-eye stars, and closer components to five pairs catalogued by previous observers, viz.: Σ 1506, Σ 2588, h 1541, h 2027, and *Espin* (unnumbered).

The following table shows the classification by distance between the components of the 800 A. stars now published:—

Distance.	No. of Stars.	Per cent.
0".00 to 0".25	58	7.3
0.26 " 0.50	162	20.2
0.51 " 1.00	169	21.1
1.01 " 2.00	193	24.1
2.01 " 5.00	210	26.3
5.01 " 5.27	8	1.0

September, 1904.

R. G. AITKEN.

THE CROCKER ECLIPSE EXPEDITIONS IN 1905.

(The following announcement by Director CAMPBELL was made in *Lick Observatory Bulletin*, No. 59.)

The next observable total solar eclipse occurs on August 30, 1905. It is remarkably well situated, and is looked forward to with great interest. The shadow path begins at sunrise south of Hudson Bay, enters the Atlantic Ocean a short distance north of Newfoundland, crosses northeastern Spain, northeastern Algiers, and northern Tunis, passes centrally over Asuan on the Nile, and ends at sunset in northeastern Arabia. The durations on the coast of Labrador, in Spain, and at Asuan are two and one half, three and three fourths, and two and three fifths minutes, respectively.

The interval of two hours and one half between the instants

of totality in Labrador and Egypt offers an unusual advantage for obtaining large-scale photographs of the solar corona, with a view to determining changes in the forms and positions of the delicate details of structure. The opportunity to bring the search for intermercurial planets to a satisfactory conclusion is also exceedingly promising. Should a new planet be observed at three stations, the interest attaching to its discovery would be heightened by the fact that its approximate orbit could be determined at once. If no planets are revealed, on good photographs, the negative results would be scarcely less valuable though certainly less interesting than positive results, and the intramercurial planet question would cease to be a pressing eclipse problem.

In Spain, the high altitude of the eclipsed Sun, and the promising weather conditions, are also very favorable for polarigraphic, spectrographic, and other investigations.

An important element in the success of eclipse observations consists in the opportunity to prepare the instrumental equipment, and the program and methods of observation, well in advance, in order that critical tests may be applied to them before the expeditions depart for their observing stations.

It is a pleasure to announce that Mr. WILLIAM H. CROCKER has again shown his interest in the science of astronomy by offering to meet the expenses of expeditions to be sent from the Lick Observatory to Labrador, Spain, and Egypt, to secure observations of the 1905 eclipse.

The provisional program for the three stations is, in the main, as follows:—

LABRADOR.

A photographic search for intramercurial planets in a region of the sky $8\frac{1}{2}^{\circ}$ wide, extending in the direction of the solar equator from 4° below the Sun to 15° above it.

The photography of the corona by means of a camera of five inches aperture and forty feet focus, of the form first used by Professor SCHAEBERLE at the eclipse of 1893.

SPAIN.

A photographic intramercurial search covering a region $9\frac{1}{4}^{\circ}$ wide, extending in the direction of the solar equator from 14° below to 14° above the Sun.

The photography of the solar corona with a camera of five inches aperture and forty feet focus.

A study of the polarized light in the corona.

The use of spectrographs provided with moving plate-holders to obtain a continuous record of changes in the spectrum of the Sun's edge at the time of second and third contacts; of spectrographs for determining the wave-length of the green coronal bright line, and, if possible, the wave-lengths of the bright and dark lines in the isolated spectrum of the Sun's edge, as nearly as possible at the time when the dark lines give way to bright ones, and *vice versa*; and of a spectrograph for recording the general spectrum of the corona.

EGYPT.

A photographic intramercorial search $8\frac{1}{2}^{\circ}$, extending in the direction of the solar equator from 4° below to 15° above the Sun.

The photography of the solar corona with a camera of five inches aperture and forty feet focus.

The photography of the general spectrum of the corona.

THE PUBLICATION OF THE CROSSLEY REFLECTOR PHOTOGRAPHS OF NEBULÆ AND STAR-CLUSTERS.

(Announcement by Director CAMPBELL in *Lick Observatory Bulletin*, No. 59.)

The late Director KEELER's observing program for the Crossley Reflector included the photography of about one hundred of the principal nebulæ and star clusters. The portions of his program available for observation in our clear summer weather were practically complete at the time of his death; but those in position during the cloudy winter months, forming nearly a half of the whole, were incomplete. After the lamented death of Professor KEELER, Assistant Astronomer PERRINE, in charge of the Crossley Reflector, made it his first duty to complete the observing program. This was accomplished in September, 1903. The importance of prompt publication of this invaluable series of photographs has been fully realized, but difficulties, both technical and financial, have existed. Plans have recently been completed whereby it is hoped to issue, within the coming half-year, a volume of the *Lick Observatory Pub-*

lications, to contain high-class reproductions of seventy-two of the principal subjects, as well as a list of several hundred new nebulae incidentally recorded on the negatives.

The purpose of this announcement is that suitable acknowledgment may be made concerning the generosity of the following friends of the Lick Observatory, who have provided funds to meet such portions of the expenses of reproducing the photographs as cannot be supplied from printing funds appropriated by the State of California:—

Mr. WILLIAM ALVORD,
Mr. E. J. DE SABLA,
Mr. JOHN B. JACKSON,
Miss MATILDA H. SMITH,
Miss JENNIE SMITH,
Mr. BENJAMIN THAW,
Mr. ROBERT BRUCE,
Mrs. PHOEBE A. HEARST,
Mr. E. J. MOLERA,
Mr. F. M. SMITH,
Mrs. WILLIAM THAW,
Mr. ROBERT J. TOBIN.

THE SUN'S CORONA.

Professor SVANTE AUGUST ARRHENIUS, of the chair of physics in the University of Stockholm, Sweden, who spent two months during the summer at the University of California, is the author of *Lick Observatory Bulletin*, No. 58, which gives his observations on the physical nature of the Sun's corona as observed at total solar eclipse. The *Bulletin* is a notable contribution to astronomical literature in that it reconciles hitherto conflicting scientific opinion concerning an important phase of the Sun's constitution. An abstract of the *Bulletin* is as follows:—

This paper was written by Professor ARRHENIUS during his recent visit on Mount Hamilton for the purpose of harmonizing the apparently conflicting results as to the sources of the coronal light obtained by the Crocker expeditions from the Lick Observatory and by the Smithsonian Institution obser-

ventions. Astronomers CAMPBELL and PERRINE held the view that the light of the inner portions of the corona is due to radiation from minute dust particles maintained at a temperature of incandescence by the enormous heat of the adjacent solar surface, and that the light from the outer corona is composed mainly of sunlight reflected and diffracted by the colder dust particles composing this part of the corona. The Lick Observatory conclusions were based upon the character of the spectrum of the corona.

The Smithsonian observers measured the quantity of heat received from the corona and were surprised to find that, even in the immediate proximity of the solar surface, the effective temperature was substantially that of the room in which they were observing. They therefore held the view that the main source of light from the corona is not the incandescence of its particles, but that the radiations are in the nature of an electrical discharge. ARRHENIUS has succeeded in harmonizing all the results of observation by showing that the particles in the region observed must be at a temperature of about 8,000° Fahrenheit, and therefore must be radiating light by virtue of their incandescence, but that the particles are so few and far between that the effective temperature observed is not the temperature of the particles themselves, but is the average temperature for the incandescent particles and the cold background of space upon which these particles are seen, here and there, in projection. The total area of the background covered by the particles in projection is but a minute fraction of its whole area. The spectroscopic and thermometric observations are completely harmonized by assuming that, in the part of the corona observed, there is but one minute dust particle for each fifteen cubic yards of space.

ARRHENIUS has, on this supposition, computed the total mass of the corona, and has found its most probable value 25,000,000 tons. This is approximately the same as that of a cube of granite whose sides are 670 feet in length. The quantity of matter involved in the corona is thus shown to be exceedingly slight, considering that it occupies a space whose dimensions in every direction amount to several millions of miles.

W. W. CAMPBELL.

ON SOME RESULTS OBTAINED BY THE D. O. MILLS EXPEDITION
TO THE SOUTHERN HEMISPHERE.*

In the extended program for determining the velocity of the solar system through space by means of the radial velocities of the stars, which has been in progress at the Lick Observatory for seven years, the need had long been felt for extending the scope of the work so as to cover the entire sky. For a full and rigorous solution of the problem it seemed absolutely imperative that the neglected portion of the southern sky within 60° of the South Pole be included. The generosity of Mr. D. O. MILLS made it possible to supply this deficiency. As is well known, the equipment sent to South America consisted of a powerful three-prism spectrograph attached to a 37-inch reflector of the Cassegrainian form. The Observatory is situated on the summit of Cerro San Cristobal in the city of Santiago, Chile, and definite work on the program was commenced on September 11, 1903, by Astronomer W. H. WRIGHT and Dr. H. K. PALMER. Up to June 1, 1904, three hundred and eight successful spectrograms had been secured.

One of the most interesting "by-products" of the spectrographic determination of the solar velocity, as carried out at Lick Observatory, has been the discovery that at least one in every seven or eight of the brighter stars are spectroscopic binaries. Similar results are being secured at the Southern Station, and in *Lick Observatory Bulletin*, No. 60, Mr. WRIGHT announces the binary character of five stars: β *Doradus*, *W Velorum*, λ *Carinal*, κ *Pavonis*, and τ *Sagittarii*.

Mr. WRIGHT has also succeeded in measuring the difference in radial velocity of the components of the visual binary α *Centauri*. From a combination of these data with the visual elements, as is well known, the parallax can be obtained with great accuracy and without the assumptions as to the great distance of the comparison-stars used which must be made in heliometrically determined parallaxes.

The values secured are:—

$$\begin{aligned}\pi &= 0''.76 \pm 0''.03 \\ \alpha &= 3.46 \times 10^5 \\ m_1 + m_2 &= 1.9\end{aligned}$$

GILL and ELKINS's value from heliometer observations was $0''.75 \pm 0''.01$, relative to the comparison-stars used, which were of average magnitude 7.6. H. D. CURTIS.

* Abstract of *Lick Observatory Bulletin*, No. 60.

GENERAL NOTES.

The *Astronomical Journal* of May 20th contains an article on the orbit of the fifth satellite of *Jupiter*, by EMILY ELIZABETH DOBBIN. The elements of Dr. COHN have been corrected by the observations of Professor BARNARD made subsequent to 1894. "The most noticeable feature of these results is the smallness of the eccentricity, as compared with that obtained by Dr. COHN and M. TISSERAND. Whether the change is real, and denotes a progressive perturbation which will end in reducing the ellipse to a perfect circle, or is an accidental one, can only be decided after another decade or more."

The computer has used only the observations of Professor BARNARD and justifies this course by the statement: "Only the observations of Professor BARNARD are considered in this paper, though I am aware of the extensive labors of Dr. R. G. AITKEN of the Lick Observatory. The homogeneity gained by excluding such observations seems to more than balance any loss in quantity."

This reasoning seems a bit odd to some of us who have been "brought up" differently. The procedure amounts, practically, to rejecting all observations except Professor BARNARD'S. There is some question as to what the author means by homogeneity, and it is to be regretted that further explanation is not given. Dr. AITKEN'S observations of the Fifth Satellite were made by connecting it with one or more of the other satellites, while Professor BARNARD'S were, I believe, made by measuring the distance of the satellite from *Jupiter's* limb. Here are two quite different methods of observing and in order to make the two series comparable it might be necessary to employ reduction factors whose exact values are not known. It is to be inferred, however, from the sentence quoted above that it would have been possible to include other observations.

Beginners usually find it very easy to reject observations and most teachers of the Method of Least Squares have to spend considerable time trying to teach their students that observations should never be rejected except for good and sufficient reasons. These can be defined in a general way, but as far as my experience goes "lack of homogeneity" has never been accepted as a good and sufficient reason. If there is a

difference between the results of two series of observations there is but one explanation, namely, that either one or both of the series is affected by systematic errors. To be sure, smaller probable errors and nicer looking results may usually be obtained by using only one series of observations, but if two or more series be employed the probabilities are that the results will be nearer the *truth*. To obtain as nearly the truth as possible should be the aim of every scientific investigation. In the present case the aim seems to have been to satisfy as nearly as possible one man's observations. Instead of rejecting other observations the computer should welcome them with open arms, and if the number becomes unwieldy it would be better, in general, to reject some of each rather than all of one. An excellent example of the benefit to be derived from combining the observations made with different instruments has been brought forth recently by Mr. HINKS, in his determination of the solar parallax from observations of *Eros*, reference to which may be found on page 225.

S. D. T.

The *Astrophysical Journal* for June contains an interesting article by Professor LANGLEY, on a possible variation of the solar radiation and its probable effect on terrestrial temperatures. By way of introduction Professor LANGLEY states: "The purpose of the present communication is primarily to discuss the validity of a surmise we may entertain, founded on observations here, as to certain possible changes in the solar constant. There is especially discussed a possible falling off of solar radiation about the close of March, 1903, as indicated by certain recent values of solar radiation computed from observations here, and compared with actually observed temperatures for eighty-nine stations of the North Temperate Zone."

Without going into the details of the observations we quote Professor LANGLEY's summary and conclusion: "A series of determinations of the solar radiation outside the atmosphere (the solar constant), extending from October, 1902, to March, 1904, has been made at the Smithsonian Astrophysical Observatory under the writer's direction.

"Care has been exercised to determine all known sources of error which could seriously affect the values relatively to each other, and principally the varying absorption of the Earth's

atmosphere. Though uncertainty must ever remain as to the absorption of this atmosphere, different kinds of evidence agree in supporting the accuracy of the estimates made of it and of the conclusions deduced from them.

"The effects due to this absorption having been allowed for, the inference from these observations appears to be that the solar radiation itself fell off about 10 per cent, beginning at the close of March, 1903. I do not assert this without qualification, but if such a change in solar radiation did actually occur, a decrease of temperature on the Earth, which might be indefinitely less than $7^{\circ}.5$ C., ought to have followed it.

"On comparing the observed temperatures of 89 stations, distributed over the North Temperate Zone, with the mean temperatures of the same stations for many previous years, it is found that an average decrease of temperature of over 2° C. actually did follow the possible fall of the solar radiation, while the temperature continued low during the remainder of the year. Stations remote from the retarding influence of the oceans show a much greater variation than that of the general mean.

"While it is difficult to conceive what influence, not solar, could have produced this rapid and *simultaneous* reduction of temperatures over the whole North Temperate Zone, and continued operative for so long a period, the evidence of solar variation cannot be said to be conclusive. Nevertheless, such a conclusion seems not an unreasonable inference from the data now at hand, and a continuation of these bolographic studies of solar radiation is of increasing interest, in view of their possible aid in forecasting terrestrial climatic changes, conceivably due to solar ones."

In the *Monthly Notices* for June Mr. HINKS, of Cambridge Observatory, presents an interesting article on the determination of the solar parallax from a reduction of photographs of *Eros*. Mr. HINKS developed some methods of reduction, and in order to test their practicability secured from several observatories measurements of all the plates taken between November 7th and 15th, which is only a small part of the interval over which photographs of *Eros* were taken. The

measurements were contributed by the observatories at Algiers, Cambridge, Minneapolis, Mount Hamilton, Northfield, Oxford, Paris, San Fernando, and Tacubaya, and a total of 295 plates are discussed in the paper.

The value of the parallax obtained is $8''.7966$, which is in very close agreement with the value used in the almanacs.

Almost all of the measurements were found to be affected by systematic errors of some sort, many of which it would have been impossible to find had the measurements made at each observatory been discussed separately. This is an excellent illustration of the point which I have attempted to bring out in the first one of these notes,—that, in general, it is always better if possible to discuss together the observations made with various instruments rather than to take alone those made by one man with one instrument to the exclusion of all others.

S. D. T.

The following notes have been taken from recent numbers of *Science*:—

Dr. MICHELERHANA, of the Observatory of Milan, has been made director of the observatory at Bologna.

Mr. H. C. RUSSELL, government astronomer of New South Wales, will retire at the end of the present year, after a service of forty-six years.

Professor SIMON NEWCOMB has been elected corresponding member of the Berlin Academy of Sciences.

M. HAMY, assistant astronomer in the Paris Observatory, has been appointed astronomer in the room of the late M. CALLANDREAU.

Dr. HANS BATTERMAN, astronomer at the Berlin Observatory, has been made director of the observatory and professor of astronomy at Königsberg.

The following interesting announcement is taken from *Science*:—

With the aid of a grant of \$10,000 from the Carnegie Institution, for use during the current year, the Yerkes Observatory of the University of Chicago has sent an expedition to Mt. Wilson (5,886 feet), near Pasadena, California, for the pur-

pose of making special investigations of the Sun. The principal instrument to be erected on the mountain is the Snow horizontal telescope, recently constructed in the instrument and optical shops of the Yerkes Observatory as the result of a gift from Miss HELEN SNOW, of Chicago. This telescope is a cœlostator reflector, the cœlostator mirror having a diameter of thirty inches. A second plane mirror, twenty-four inches in diameter, reflects the beam north from the cœlostator to either one of two concave mirrors, each of 24-inch aperture. One of these concave mirrors, of about sixty feet focal length, is to be used in conjunction with a solar spectrograph of five inches aperture and thirteen feet focal length; a spectroheliograph of seven inches aperture, resembling the Rumford spectroheliograph of the Yerkes Observatory; and a stellar spectrograph provided with a large concave grating and mounted in a constant-temperature laboratory. It is hoped that it will be possible with this stellar spectrograph to photograph the spectra of a few of the brightest stars. For fainter stars the spectrograph is to be provided with several prisms, for use singly or in combination. The second concave mirror of the cœlostator reflector is designed to give a large focal image of the Sun, especially adapted for investigations with a powerful spectroheliograph and for spectroscopic studies of sun-spots and other solar phenomena. The focal length of this mirror is about 145 feet, so that it will give a solar image about sixteen inches in diameter. The spectroheliograph for use with this large solar image is to be seven inches aperture and thirty feet focal length. For the present, until a suitable grating can be obtained, the dispersive train of this instrument will consist of three prisms of 45° refracting angle, used in conjunction with a plane mirror, so as to give a total deviation of 180° . The motion of the solar image, of which a zone about four inches wide can be photographed with the spectroheliograph, will be produced by rotating the concave mirror about a vertical axis by means of a driving-clock. A second driving-clock, so controlled as to be synchronous with the first, will cause the photographic plate to move behind the second slit. Three slits will be provided at this point, so as to permit photographs to be taken simultaneously through as many different lines of the spectra. It is hoped that this

spectroheliograph will prove to be well suited for use with some of the narrower dark lines of the solar spectrum.

The work of the expedition is under the immediate direction of Professor GEORGE E. HALE, director of the Yerkes Observatory. During his absence Professor E. B. FROST will be in immediate charge of the Yerkes Observatory, with the title of acting director. Professor FROST will also be the managing editor of the *Astrophysical Journal*. Mr. FERDINAND ELLERMAN and Mr. WALTER S. ADAMS will be associated with Professor HALE in the work on Mt. Wilson.

Professor S. W. RITCHEY, superintendent of instrument construction at the Yerkes Observatory, will be in charge of an instrument-shop which is being fitted up for the expedition to Pasadena.

The following obituary notice of THEODORE BREDICHIN is taken from the July number of the *Observatory*:—

With regret we have to announce the death of this distinguished Russian astronomer, which took place on May 14th last. BREDICHIN, who was a member of a noble family, was born at Nicolajoff on December 8, 1831. He was first educated at the Richelieu Lyceum in Odessa, and in 1851 became a student in the physico-mathematical faculty of the University of Moscow. In the year 1857 he was made Professor of Astronomy, and in 1873 Director of the University Observatory. He approached astronomy from many sides. He was the first in Russia to make spectroscopic observations of stars. He made observations of star-positions, of time of swing of pendulums, but his most famous works are his valuable contributions to the theory of the forms of comets and of meteor streams. In the year 1891 he succeeded OTTO STRUVE as Director of the Russian National Observatory at Poulkova, from which office he retired in 1894 on account of advancing years and the state of his health, for which the climate of Poulkova was not suitable.

Dr. ISAAC ROBERTS, F. R. S., died in July last in his seventy-fifth year. A large portion of his life was devoted to spectrum analysis, astronomy, and other kindred branches of science.

For several years he pursued stellar photography with powerful instruments specially constructed for the purpose, and succeeded in adding considerably to the knowledge of the stars, clusters, and nebulae. In 1885 he commenced to chart by photography the stars in the northern hemisphere of the sky, but ere he had been a year engaged upon this work the French astronomers arranged that the charting of the stars should be done internationally on a uniform scale by instruments of similar construction. Dr. ROBERTS thereupon turned his attention to special researches on star-clusters and nebulae, with long exposures of the photographic plates. These photographs have been regarded with the highest interest and admiration wherever they have been exhibited. He devised a method and a machine by which the stars that have been photographed can with accuracy be engraved directly from the negatives on copper plates for the purpose of printing; the machine is also adapted for measuring the positions and magnitudes of the stars.

The annual visitation of the Royal Observatory, Greenwich, took place on the first Saturday of June. The visitors included Sir DAVID GILL, Director of the Observatory at Cape of Good Hope, who was on a visit to England.

One rather unexpected feature in the Astronomer Royal's report is that, in spite of the unprecedented rainfall of last year, the number of observations in all departments is unusually high, the number of transits obtained with the transit circle being 13,270, the greatest number on record. In addition to the continuous observation of Sun, Moon, and planets, this instrument is devoted to the formation of a complete catalogue of all the stars from the first to the ninth magnitude that lie within 26 degrees of the North Pole. The total number of stars is about 10,000, five observations of each being required. This work is so well advanced that it has been decided to close the observations for the catalogue at the end of 1905, a year earlier than was originally intended.

The Moon was observed 106 times with the transit circle and 88 times with the altazimuth, the results showing that the Right Ascensions given in the Nautical Almanac require to be increased by 0.19 second on the average. The amount of the

correction has been increasing rather rapidly in recent years, indicating that the mean motion used by the Nautical Almanac (HANSEN corrected by NEWCOMB) is slightly too small.

One important feature of last year's work has been the exhaustive analysis to which the observations of the Moon made at Greenwich during the last 150 years have been subjected by Mr. COWELL. He devised a method which enormously diminishes the labor of the analysis. One of the most interesting terms is that known as the parallactic inequality, from which the Sun's distance is deducible; the coefficient of this is found to be 124.75 seconds of arc, implying that the Sun's parallax is 8.778 seconds and his distance 93,130,000 miles. The semi-diameter of the Moon is found to be 933.75 seconds of arc, about one third of a second less than HANSEN's value, and one second greater than the value deduced from occultations, the difference being chiefly due to irradiation at the Moon's bright limb. It would appear, therefore, that this irradiation is less than was formerly supposed. It may be noted that the Nautical Almanac will shortly supply predictions for Greenwich of occultations of stars down to the seventh magnitude, which will considerably increase the number of predicted phenomena. The great 28-inch equatorial has been devoted entirely to double-star work; 512 pairs were observed, of which 178 were less than one second apart, and 85 less than half a second. The two most difficult pairs were *Kappa Pegasi* (observed on 14 nights) and *Epsilon Hydra* (observed on four nights), the distance in each case being one tenth of a second.

A very interesting photograph of BORRELLY's Comet was obtained on August 1st, with an exposure of forty minutes; it shows nine distinct tails arranged in the form of a fan, the shape resembling that of SWIFT's Comet of the preceding year.

The Sun was photographed at Greenwich on 220 days, and plates from Mauritius and India are available on 122 days, leaving only 23 days in the year without a record; some of these will be filled up, as there are some more plates to come from Mauritius. The solar activity shows a notable increase; there were only 25 days without spots, as compared with 190 in the previous year, and the mean daily spotted area increased sixfold.

It may be mentioned that a series of photographs illustrat-

ing the work of the Royal Observatory has been sent to the St. Louis Exhibition.—Extract from *The Times* of June 6, 1904.

Four hundred and fifty guests were invited by the French Astronomical Society to pass the night on the Eiffel Tower, Paris, on "Tuesday, the 21st of June, date of the Summer Solstice." The gathering was the first of the sun festivals which the Astronomical Society, inspired by its poetically tempered ex-President, M. FLAMMARION, has resolved to perpetuate. It is simply a scientific festival, with the propagation of popular interest in the wonder and beauty of the universe as one of its chief motives. All were congregated on the first landing of the tower, when the crash of a gun down below, on *terra firma*, announced that the Sun had at that moment reached the solstice. Time, twenty-eight seconds past nine.

The venerable President of the Society, M. JANSSEN, welcomed his guests at the theater on the first landing and read a short discourse, after which M. FLAMMARION delivered an eloquent address on Sun worship in the world's past, on the Sun's influence in the stellar system, and on astronomical discovery. The address was followed by a great many beautiful illustrations projected on a white screen. After that there were hymns to the Sun, invocations to the Sun and prayer to the Sun, from composers and poets, sung and repeated by artists from the Opera. A luxurious luncheon at midnight followed. Thereafter about fifty guests went to the top of the tower and waited for sunrise.—From the London *Daily News*.

The honorary degree of D. Sc. has been conferred by the University of Oxford on Sir DAVID GILL, Astronomer Royal, Cape of Good Hope.

COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to WILLIAM R. BROOKS, astronomer, Geneva, New York, for his discovery of an unexpected comet on April 16, 1904.

The Committee on the Comet-Medal:

W. W. CAMPBELL,
CHAS. BURCKHALTER.

OFFICERS OF THE SOCIETY.

Mr. GEO. C. EDWARDS *President*
 Mr. S. D. TOWNLEY *First Vice-President*
 Mr. CHAS. S. CUSHING *Second Vice-President*
 Mr. A. O. LEUSCHNER *Third Vice-President*
 Mr. R. G. AITKEN }
 Mr. F. R. ZIEL } *Secretaries*
 Mr. F. R. ZIEL *Treasurer*
Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING,
 EDWARDS, LEUSCHNER, PARDEE, PIERSON, TOWNLEY, ZIEL.
Finance Committee—Messrs. CUSHING, PIERSON, LEUSCHNER.
Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.
Library Committee—Messrs. TOWNLEY, BABCOCK, Miss O'HALLORAN.
Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), PIERSON, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLE.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.
 (February, April, June, August, October, December.)



CONTENTS.

	PAGE
Monck, W. H. S. —The Sun's Velocity in Space	189
Smith, Elliott. —Star Catalogues.	193
Moore, J. H. —The Loss of Light by Absorption and Reflection in the 36-inch Objective.	202
The Loss of Light by Diffraction at a Narrow Slit.	203
O'Halloran, Rose. —Variable Star Notes	207
McNeill, Malcolm. —Planetary Phenomena for September and October, 1904	210
Planetary Phenomena for November and December, 1904.	212
Notices from the Lick Observatory	215
General Notes.	223
Comet-Medal	232
Officers of the Society.	233

9000

PUBLICATIONS

OF THE

ASTRONOMICAL SOCIETY

OF THE PACIFIC.



VOLUME XVI.

NUMBER 99.

1904.

SAN FRANCISCO:
PRINTED FOR THE SOCIETY

1904.

[Entered at Post Office at San Francisco, Cal., as second-class mail matter.]

COMMITTEE ON PUBLICATION.

ROBERT G. ATKIN, Mt. Hamilton, Cal.

FRANK SCHLESINGER, Williams Bay, Wis.

SIDNEY D. TOWNLEY, Ukiah, Cal.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XVI. SAN FRANCISCO, CALIFORNIA, DECEMBER 10, 1904. NO. 99.

ON DOUBLE STARS.*

BY R. G. AITKEN.

In the ten minutes allotted to me this morning I wish to offer some general considerations relating to double-star astronomy, to describe more particularly the work now in progress at the Lick Observatory, and to make some suggestions as to the lines of future investigation that seem to me to promise the largest returns for the time and labor invested.

Only a century has passed since Sir WILLIAM HERSCHEL announced the existence of physical systems among the stars, and but little more than three quarters of a century since STRUVE laid the sure foundations for a new department of sidereal astronomy by the publication of the "*Mensuræ Micrometricæ*." From an astronomer's view-point, these are short periods, and double-star astronomy is still in the primary stages of its development. Still, far more has been accomplished by the zealous efforts of its devotees than can be mentioned even briefly in the limits of this paper.

Taking account only of the double stars within 120° of the North Pole, BURNHAM, in 1896, found that nearly eleven thousand objects were included in the published catalogues. Less than half this number deserved the name of double star, judged by our present standards; for in the absence of any criterion based upon observation, the earlier observers very properly made their limits much wider than would be excusable to-day. Of the four thousand or five thousand objects that might fairly be called double stars, not more than eighteen hundred had

* Read before the Section Astrometry, International Congress of Arts and Science, St. Louis, September 21, 1904.

distances of $2''$ or less. Nearly eight hundred of these close pairs were discovered by BURNHAM himself, and many of the others were added by HOUGH, SEE, and other recent observers. Between two hundred and three hundred pairs had given definite evidence of orbital motion, and in about fifty cases the observed motion was sufficiently great to form the basis for approximately accurate orbits.

During the nineteenth century astronomers devoted a great deal of time to the important task of measuring these double stars, especially those contained in the catalogues of the two STRUVES and of BURNHAM, and a vast amount of observational material was accumulated. Unfortunately these measures as a whole are not readily accessible to observers, being widely scattered through the publications of observatories, the transactions of academies of science, and the scientific periodicals of Europe and America. For this reason much time has been wasted in unnecessary duplication of measures. Even more time, perhaps, has been thrown away because too many observers in their zeal have tried to make measures under unsatisfactory observing conditions and often of objects beyond the power of their telescopes. Such work only introduces confusion, and must ultimately be rejected as valueless.

So far as the double stars already discovered are concerned, I am convinced that our first need is a General Catalogue that will give not only the position of every known double star, with its description, but also enough measures of every pair to show the nature of the motion, if motion has been observed, together with complete references to all published measures. Important contributions in this line have recently been made by INNES with his "Reference Catalogue of Southern Double Stars," and by HUSSEY with his complete monograph on the "Otto Struve Double Stars." A much more important, because far more comprehensive, work is the General Catalogue that BURNHAM has been engaged upon for many years. This work is now in press, and all who are interested in double-star astronomy rejoice at the prospect of its early publication.

In the second place, the experience of the past century has made it clear that the wider double stars of the older catalogues need very little attention, and that even the moderately close pairs—those having distances of from $2''$ to $5''$ —need

be measured but once in ten to twenty years. Observers having access to good telescopes should therefore devote their time mainly to the measurement of the double stars with distances under $2''$, especially those that have already given evidence of motion and the very close pairs of recent discovery; and they should repeat the measures of the same stars annually or biennially, according to the rapidity of the observed motion, for as many years as possible. Such a systematic series of measures of two hundred or three hundred selected stars, made by a single observer working with an adequate telescope under good conditions, will in twenty years' time add more to our knowledge of the binary systems than sporadic measures of fifty times as many pairs by a dozen observers.

But at the present time, when many leaders of astronomical thought are making extensive researches into stellar statistics, there are other questions relating to double stars, besides the theory of the motion in any particular system or systems, that are of the greatest interest.

What is the number of double stars relatively to all the stars to a given magnitude? Is this ratio the same for the fainter stars as for the brighter ones? Does it vary in different parts of the heavens, and, if so, what is the cause of the variation? These and other questions relating to double-star statistics demand an answer.

The catalogues of the HERSCHELS and the STRUVES do not afford the data needed for investigations of this nature, for the discoveries of BURNHAM, HOUGH, and others have demonstrated that the surveys of these early observers were not nearly so complete as their immediate successors had supposed. And it is also a fact that the work of none of the later double-star observers, not even that of BURNHAM, has been thorough in the sense that every star to a given magnitude in a given sky area has been examined.*

A systematic search for double stars that will include the careful examination of every star to the eighth or ninth magnitude with a good modern telescope under favorable observing conditions is therefore a prime requisite for reliable statistical researches on double stars.

* This statement, of course, applies only to telescopic stars. BURNHAM has undoubtedly examined every naked-eye star visible in our latitude, most of them repeatedly.

There are other good reasons for making such a survey of the sky. Accurate meridian-circle observations are now extending to the stars of the ninth magnitude, and stars to this magnitude, and even fainter ones, are in daily use as reference-points in the measures of photographic plates. But moderately close double stars are obviously not suited to such uses; yet they will usually escape detection in meridian-circle observations and very often also on the photographic plates.

Such considerations as these led me, in 1899, to begin a systematic examination of all the stars given in the Bonn-Durchmusterung as of the 9.0 magnitude or brighter. This limit was adopted because it would include a number of stars (over one hundred thousand in the northern hemisphere) sufficiently large for reliable statistical studies, and would at the same time include nearly all the stars likely to be observed with accuracy on the meridian.

I had hardly begun my search when I found that Professor HUSSEY had independently decided to undertake a similar piece of work. We at once made plans to divide the field between us and to make our survey thoroughly systematic.

The sky from the North Pole to 22° South Declination was divided into zones of varying width, and these were so apportioned that about half of this sky area was assigned to each observer. We decided to chart to a convenient scale all the stars to be included in our survey, also marking on our charts the position and description of every double star already known. Each star was to be examined on at least one good night, and every new double star found whose components were separated by $5''$ or less was to be measured on two or more nights and catalogued. We adopted this limit of distance after a careful consideration of the known binary systems as being wide enough to include all pairs at all likely to prove of interest as binaries. At the same time this limit was none too wide if we wished our lists to include all pairs likely to affect meridian observations or the measures of photographic plates.

Having formulated our general programme, we have given part of our time for the past few years to its execution, each observer working independently but in entire harmony with the other. Our survey is not quite half completed, but the results already obtained have far exceeded our expectations.

At the present time* Professor HUSSEY has found 1,035 new pairs, while my own discoveries exceed 875. These new pairs are practically all within our limit of 5", seventy-three per cent. of them have distances of 2" or less, and 142 are very close pairs, with distances under 0".25. The number of pairs of this latter class in all other catalogues combined is less than 100.

I have made counts in several zones 4° wide, and from 90° to 360° long, which I have thoroughly examined, including in all more than twelve thousand stars to the 9.0 magnitude. In these zones the ratio of new double stars to the whole number of stars examined varies from 1:27 to 1:36; hence I conclude that a ratio of 3:100 will be a fair average for the whole region so far surveyed. This ratio refers only to the new discoveries. When we include such of the double stars previously known as fall within our limits of magnitude and distance, counts that I have made in two long zones show that the ratio of double stars under 5" to all the stars to 9.0 magnitude is 1:18 or 1:20.

New pairs are found as readily in the well-observed northern sky as in the zones south of the equator, but neither the new pairs nor those previously known are uniformly distributed over the sky. There are large areas that contain very few known double stars in which we have added but few new pairs. In other large areas the ratio of double stars to all stars to 9.0 magnitude rises as high as 1:8. It is clear that such facts as these have a physical significance, and must be taken into account in framing adequate theories of cosmogony.

These ratios are only first approximations, but we are satisfied that, when our programme is fully carried out, our charts will afford ample data for the discussion of all statistical questions relating to the double stars within 112° of the North Pole. Of course, we do not suppose our search to be exhaustive, but we have very good reasons for thinking that the percentage of visual double stars that are overlooked is too small to have any sensible effect upon general conclusions.

No argument is needed to show the desirability of extending to the South Pole the search for new double stars on the systematic plan of the survey now in progress at the Lick Observatory. Indeed, when we consider how little attention the

* September 10, 1904.

southern double stars have received in the past and how completely they are being neglected at present, it is clear that this is the most important double-star work that can now be undertaken,—especially if the programme is made to include the re-measurement of the closer pairs already known.

From our experience at the Lick Observatory, it is my opinion that such a survey can be carried out by a single observer in four or five years' time, provided his telescope is as favorably located as those on Mt. Hamilton, and that a refractor of from twenty-four to twenty-seven inches aperture, all things considered, is best adapted to the work.

We find that on good nights (seeing three or more on a scale of five) we can examine from two hundred to two hundred and fifty stars per night without undue strain upon our eyes. Assuming that the number of stars to 9.0 magnitude in the southern hemisphere is not much greater than in the northern, six hundred nights would suffice to examine the stars to this magnitude south of -22° Declination, and to measure on two or three different nights each new double star discovered. At Mt. Hamilton, six hundred good nights would ordinarily mean about four years' time.

Examination of the catalogues of double stars discovered at the Lick Observatory will show that very few pairs are closer than $0''.15$, and that the percentage of pairs with one component fainter than 14.5 magnitude is also very small. The visual double stars, therefore, that are beyond the reach of a good 24-inch refractor are so few that such a telescope is adequate to the work, and the greater ease with which it can be handled, as well as the small relative cost, seems to recommend it for this purpose even in preference to another 36-inch. This assumes, of course, that the mechanism of the mounting, dome, and floor of the smaller telescope is as perfect and as convenient for the observer as that of our 36-inch.

When such a survey of the entire sky has been made it will be possible to discuss double-star statistics with reasonable assurance of reaching definite and reliable conclusions. This alone will be ample compensation for the labor and time required to carry it out. The very large number of interesting binary systems it will certainly reveal to us is a strong additional incentive to the work.

PLANETARY PHENOMENA FOR JANUARY AND
FEBRUARY, 1905.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

New Moon, Jan. 5, 10 ^h 17 ^m A.M.	New Moon, Feb. 4, 3 ^h 6 ^m A.M.
First Quarter, " 13, 12 11 P.M.	First Quarter, " 12, 8 20 A.M.
Full Moon, " 20, 11 14 P.M.	Full Moon, " 19, 10 52 A.M.
Last Quarter, " 27, 4 20 P.M.	Last Quarter, " 26, 2 4 A.M.

The first of the four eclipses of the year will occur on February 19th, and will be a partial eclipse of the Moon. It will be visible generally throughout the eastern hemisphere, but not in the western. The maximum obscuration will be a little less than one half of the Moon's diameter.

Mercury will be a morning star throughout January and February. It passes inferior conjunction with the Sun December 31, 1904, reaches greatest western elongation on January 22d, and will come to superior conjunction on March 9th. It is too close to the Sun to be seen on January 1st, but rapidly increases its distance, so that it rises more than an hour before sunrise before the middle of the month. During the latter half of January the interval is never less than an hour. After February 1st the interval becomes much shorter, and the planet is too close to the Sun for naked-eye observations after the first few days of the month. The greatest elongation, on January 22d, is 24°. This is rather greater than usual, as the planet is then within a short distance of aphelion, which comes on February 9th.

Venus continues as an evening star, remaining above the horizon about three and one half hours after sunset on January 1st, and this interval increases to nearly four hours during February. It reaches its greatest east elongation, 46° 41', on February 14th. The part of the ecliptic in the neighborhood of the planet is much nearer the pole than the place occupied by the Sun, and this makes the interval between the setting of the Sun and the setting of the planet much greater than it is usually at the period of greatest elongation. During the two months' period the planet moves about 57° eastward and 20°

northward from *Capricorn* through *Aquarius* and *Pisces* to the extreme eastern part of the latter constellation. On the morning of February 3d it is very near the vernal equinox. The actual distance of the planet from the Earth diminishes quite rapidly, and there is consequently a marked increase in brightness, but the planet will not attain its maximum brilliancy until near the end of March.

Mars rises at 1:15 A. M. on January 1st and at 11:35 P. M. on February 28th. It moves about 25° eastward and 8° southward from a point in *Virgo* a little east and north of *Spica*, α *Virginis*, to the eastern part of *Libra*, and at the close of February will be about 18° west and north of *Antares*, α *Scorpii*. Its actual distance from the Earth diminishes about fifty-five millions of miles between January 1st and February 28th, and at the latter date its distance from us is about the same as Earth's mean distance from the Sun. This causes the planet to increase about two and one half times in brightness from January 1st to February 28th. *Mars* will thus be quite a conspicuous object, although from February to the time of opposition in May the gain will be in a still greater ratio.

Next to *Venus*, *Jupiter* is the brightest object in the evening sky. It sets at about 1 A. M. on January 1st, and at a little before 10 P. M. on February 28th. It is therefore well placed in the southwestern sky for evening observation. It moves about 7° eastward and 3° northward in the eastern part of *Pisces*, and at the end of February it is only about 5° east and south of *Venus*. The two planets will be in conjunction early in March.

Saturn will also be an evening star during the greater part of the period; but is much lower down and apparently nearer the Sun than *Jupiter* is. It may, however, be easily seen in the evening twilight throughout January. It sets about three hours after sunset on January 1st, and only about an hour after on February 1st. It comes to conjunction with the Sun, and changes from an evening to a morning star, on February 12th, but does not reach a great enough distance from the Sun by the end of the month to be seen with the naked eye.

Uranus is a morning star very close to the Sun on January 1st, but gradually increases its apparent distance from that body, so that by the end of February it rises about three hours before sunrise. It moves about 3° eastward in *Sagittarius*, and

is a short distance north of the "milk-dipper" group in that constellation.

Neptune passed opposition with the Sun toward the end of December, and is therefore above the horizon during most of the night. It is in the western part of *Gemini*, and moves about 1° westward during the two months.

I.—A PROPOSED METHOD FOR THE MEASUREMENT AND REDUCTION OF SPECTROGRAMS FOR THE DETERMINATION OF THE RADIAL VELOCITIES OF CELESTIAL OBJECTS.

II.—APPLICATION TO A STUDY OF THE VARIABLE STAR *W SAGITTARII*.*

INTRODUCTION.

Beginning thirty-five years ago, when HUGGINS and VOGEL first made application of DOPPLER's principle to the determination of radial velocities of stars, the methods employed in this work have been developed until at present an efficient and practically uniform system has been adopted in the various astrophysical observatories. In 1888, when the attempt was made at Potsdam to record photographically the displacement of lines in the stellar spectra, the problem was placed on a firm basis. Subsequently, through improvement in the construction of spectrographs, a more accurate knowledge of the wave-lengths of spectral lines, and signal advances in the methods of measurement and reduction of the spectrograms, the results have attained their present degree of accuracy. The probable error of 22^{km} per second for an average case of velocity determination with the older methods has been reduced to a few tenths of a kilometer at the present time.

Flexure and temperature change during exposure may be said to play no part in the performance of the modern properly equipped spectrograph, and other observational

* Dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of California. (Abstract. Complete paper published as *L. O. Bulletin*, Number 62.)

sources of error are well under control. Undoubtedly, the spectrograms of to-day contain information regarding the velocities of celestial light-sources more precise than our present methods of measurement and reduction are capable of bringing out. In these methods there exist certain recognized sources of accidental and systematic error which must be eliminated if the coveted hundredth of a kilometer can ever have any significance.

PART I.

METHODS OF MEASUREMENT AND REDUCTION OF SPECTROGRAMS.

The plan of procedure that has been widely adopted, subject to slight variation in the case of different observers, may be briefly described. The spectrogram is measured twice, direct and reversed, on an engine supplied with a microscope of adjustable magnifying power, rigidly mounted over a plate-carriage which is moved by delicate screw and micrometer system in one coordinate only, in the direction of extension of the spectrum. A set of measures includes the list of micrometer readings which correspond to the positions of the plate-carriage when the various spectral lines, both bright and dark, occupy in turn a given position with reference to some fixed point in the focal plane of the microscope. These readings, together with the laboratory determinations of the wave-lengths of the spectral lines employed for the measurements, constitute the data necessary for the determination of the radial velocity of the source emitting the light, in terms of the accepted standards of velocity. From the micrometer readings and wave-lengths corresponding to not less than three known lines in the comparison or solar spectrum, the constants of the Hartmann-Cornu interpolation formula* are easily computed. By this formula micrometer readings are readily transformed into approximate wave-lengths, and *vice versa*.† If, now, each plate is to be reduced independently, as at Yerkes Observatory,‡ the constants of the empirical interpolation curve are computed as above from three or more comparison lines. Corrections to this curve are determined by comparison of the adopted and interpolated wave-lengths of the comparison lines, and

* *Astrophysical Journal*, Vol. VIII, page 218. *Astronomische Nachrichten*, Nr. 3702.

† *Publications of the University of Chicago*, Vol. VIII, page 150. *Astrophysical Journal*, Vol. XV, No. 1.

are plotted as functions of the micrometer readings or the λ 's themselves. It then remains to compute by means of this corrected interpolation formula the wave-lengths corresponding to the micrometer settings on the lines of the spectrum to be measured. We thus obtain the actual wave-lengths of these lines as affected by the motion of their source relatively to the observer. From the known wave-lengths of these lines, occurring in the spectrum of a light-source at rest with reference to the observer, a simple application of DOPPLER'S principle will yield the desired radial velocity of the star. If, on the other hand, the dispersions of one or more solar plates* be taken as standards, by measures on the comparison lines of a stellar spectrogram, the micrometer readings on the star lines themselves are reduced to the selected dispersion, and may be compared directly with the computed readings of the same lines in the fundamental table. In point of accuracy, there seems to be no choice between these two methods, but the latter one is undoubtedly shorter. The sources of error which are shared by both, I shall briefly review.

(a) *Change in film.*—The actual shape of the photographic film while the plate is being exposed is never reproduced, owing to distortions ascribable to temperature change and the processes of development and drying, but the effect of these distortions on velocity determinations is minute and intangible, especially when many well-distributed comparison lines are employed.

(b) *The measuring-engine.*—(1) Errors in screw.—Errors due to inequalities in the pitch of the micrometer screw, whether periodic or otherwise, are usually negligible in modern engines. They may, of course, be eliminated by application of small corrections to the measures, but are essentially inoperative in most velocity work.

(2) Temperature change during measures.—The effect of temperature change on the measuring-engine during measurements may play an important part unless considerable care is exercised. Measures should not be begun until the micrometer-head has been in contact with the hand for a short time, and during the measures the room temperature should be kept nearly constant. In my own work, after completing a plate,

* *Astronomische Nachrichten*, Nr. 3702. *Astrophysical Journal*, Vol. VIII, page 124.

I have tested the temperature shift by setting back on the lines first measured, and have invariably found some discrepancy. In one solar plate in particular, which had required considerable time for measurement, this shift amounted to about .003^{mm}, or the equivalent of seven kilometers' velocity. This led me to test the character of the shift by remeasurement of some of the remaining comparison lines on the plate. The plot of differences thus obtained approximated a straight line which gradually approached the original curve. Evidently the temperature change was progressive, and was entirely taken up in the first curve. Here, again, the advantage of an even distribution of star and comparison lines is apparent. Evidently, also, the "smoothing out" of curves of residuals from interpolation formulæ should not be practiced without due caution, for temperature change during the measures may produce very appreciable distortions in such a plot.

(c) *Subjective errors*.—Discrepancies arising from accidental errors of setting and from personal equation are among the most important to be considered. The former can be reduced only by long practice and the employment of a greater number of lines; the latter have been largely eliminated by the reversal of the spectrogram on the engine,* but it should be noted that in the reversal of a plate the spectrum is simultaneously inverted. Thus, in general, it would hardly be said that the effect of personal equation is entirely compensating in the two measures, for the appearance of a line after inversion might be so changed as seriously to interfere with the duplication of the conditions which existed before reversal. Further, in case of a straight-slit spectrograph the curvature† of the spectral lines would seriously interfere with the elimination of personal equation in this way.

(d) *Errors due to the assumption of wave-lengths*.—(1) An instrumental defect.—A source of error by no means inappreciable is found in the relative displacement of comparison and absorption lines due to imperfect focal conditions which obtain outside of given narrow regions of the spectrum, corresponding to the rays which pass through the prism train at

* *L. O. Bulletin*, No. 15, and *Astrophysical Journal*, Vol. XV, page 208.

† Curved slits are used on the Mills spectrograph. They give straight spectral lines, which is a decided advantage.

minimum deviation, or corresponding to the intersections of the focal curve with the plane surface of the photographic plate. The so-called wings, which seriously impair the definition of the outlying lines of the comparison spectrum, undoubtedly persist far into the region of apparently sharp focus, giving rise to errors in the measured positions of the bright lines. The corresponding displacements of the absorption lines of the stellar spectra, due to the same cause, are certainly much smaller, if at all appreciable. This difference is due to the fact that much light is concentrated in the bright lines, many of which are strongly exposed in order to bring out the fainter features of the comparison. Thus the wings, though they share a relatively small part of the light, may become quite as dense as the sharp part of the lines, for the density of the sharp part of the lines is but slightly affected by light after a certain time, while the wings continue to spread.

(2) Physical differences.—Aside from subjective errors of measurement, there is no greater source of uncertainty in the reduction of spectrograms than that which arises from the assumption of wave-lengths for the star and comparison lines from ROWLAND'S solar tables. It is doubtful if the conditions of density and internal motion in the Sun and spark are sufficiently alike to warrant this procedure. But until better determinations of spark wave-lengths are available, there seems to be no alternative. A careful discussion of the matter by FROST and ADAMS* has led to the conclusion that "In the present state of our knowledge we . . . cannot say with any certainty how much our results are affected by the use of solar wave-lengths for our Ti lines; but presumably by an amount corresponding to less than 0.02 tenth-meters, or about 1.4 kilometers, and perhaps very much less." Wave-lengths in star and Sun may differ by small amounts, due to pressure, etc., but it seems practicable to assume agreement in the case of solar-type stars. In other cases the chances seem favorable.

•(3) Errors in ROWLAND'S table.—ROWLAND'S determinations of solar wave-lengths are probably relatively accurate to the nearest hundredth of an Ångström Unit. Their absolute value need be known only approximately for velocity work.

(4) Errors in practice.—In actual performance some ap-

**Publications of the University of Chicago*, Vol. VIII, page 155.

parently good lines are found to yield consistently poor results, which usually lead to their final rejection. Errors in wavelengths or intensities in ROWLAND'S table, or close lines in the star, may be responsible for the trouble. However that may be, there are undoubtedly among the lines retained many which are similarly in error, but in a smaller degree. It simply remains to eliminate such lines as soon as they can be detected, though the uncertainty of proceeding in the dark in this regard is far from satisfactory.

(e) *Elimination of these errors.*—For errors due to change of film and inaccuracies in the measuring-engine, including temperature change during measures, adequate remedy has been proposed, but no elimination of the remaining uncertainties incident to present methods seems possible without a radical change in the system employed. As long as the wavelengths determined from measures with the grating or interferometer by an observer of one personal equation are employed by another observer of a different personal equation to represent his measures of corresponding lines as produced by a different spectroscope, it can hardly be expected that the results of various observers will be entirely consistent. The problem demands that the conditions which obtain in the production, measurement, and reduction of a spectrographic plate of a star should be exactly duplicated in the production, measurement, and in general the reduction, of the plate from which the fundamental data for velocity determinations are secured. The same spectrograph should produce both plates. They should be measured by the same observer with the same measuring-engine. And, finally, they should be reduced in parallel. These requirements are clearly most exacting, but as a suggestion of a means toward this end, I propose the following method, which, as far as I know, has never been applied in this way.

A PROPOSED METHOD FOR THE MEASUREMENT AND REDUCTION OF SPECTROGRAMS.

Proceeding as in case of a stellar exposure with the spectrograph in final adjustment, from which it must not be disturbed, a source of accurately known velocity, such as the sky or Sun, is photographed with the comparison in the usual

manner. Then the measures upon the comparison and continuous spectra of this plate with some engine by any observer will constitute his fundamental standard table for the engine and spectrograph used. These measures of the bright and dark lines of a plate of the sky or Sun and spark will fix the relative positions of the Fraunhofer and comparison lines for a known velocity, and will constitute a velocity-standard table. For the determination of the velocity of any celestial object of the same characteristics as the standard source, it is only necessary to duplicate the exposure and measures of the standard plate and compare directly the relative positions of corresponding lines of the two sources referred to the comparison spectrum of their respective plates. In the reduction of a stellar plate for velocity determination, we first reduce the star measures to the dispersion of the standard plate by forming a simple plot with micrometer readings as abscissæ and differences in settings on comparison lines as ordinates. For the star lines the reductions to fundamental dispersion are read directly from this plot. If these reductions are applied to the readings on the stellar spectrum, the measured positions of any dark line on the Sun and star plates will differ by an amount proportional to the relative velocity toward the Earth of the star and Sun.

The assumptions in this method are fundamental in every case of velocity determination. Further assumptions treated above as incident to other methods are here eliminated by the comparison of artificial lines with artificial lines and dark lines with dark lines. The advantages of this simple system need only be mentioned. Errors in the screw of the measuring-engine are eliminated for small displacements, such as are found in stellar spectra, if the standard and star plates occupy identical positions on the plate-carriage during measures. Personal equation is well controlled without the reversal of the spectrogram, and may be closely followed by frequent measures of standard plates. It may even seem preferable not to reverse the plate, for, as I have suggested, the curvature of lines may introduce a variation of this unaccountable source of error. The magnitude of accidental errors of setting is not affected by the use of this method, but with the greater number of lines available in solar-type stars particularly, the reliability

of the means from any plate is clearly increased. Uncertainties due to imperfect focal conditions are not only largely eliminated if the exposures on comparison and star are consistent in star and standard plates, but the region of spectrum available for measurement can be extended without fear of encountering difficulty. The number of lines available is further augmented for solar-type stars by the possibility of including blends, which are clearly reliable under this method. Until tests are made with high-dispersion instruments, it is difficult to predict the extent of the advantage of this increase of the measurable lines for this case; but for low-dispersion instruments in my own experience with a magnifying power of twenty-five, the number of available lines increased from twenty to one hundred and seventy; and with a power of ten, though practically no lines could be used with methods depending on wave-lengths, sixty-five lines gave good results for velocity determinations. But for the present the chief advantage of the method lies in its independence of accurate relative or absolute values of the wave-lengths or intensities of the spectral lines of the spark or continuous spectrum. For the determination of the factors necessary to convert micrometer displacements into kilometers, rough relative values of the wave-lengths of three favorable spark lines are needed, but, aside from this, there is no necessity for data of this kind. It is, possible to make final definitive measures at once.

In the application of this method any degree of refinement can be introduced at the will of the observer. The number of plates employed to form a standard table can be increased until the full possibilities of the spectrograph and measuring engine are realized. By comparison of standard plates any errors due to temperature change in the instrument can be detected, and tables can be prepared for different temperatures, if desired. Standard plates can be prepared occasionally and measured, along with the regular observing list, as checks on the constancy of the results. For absolute checks of the performance of the method lunar and planetary spectrograms are of course available, but the determination of the sky or solar velocities furnish equally reliable checks, and at the same time afford data for strengthening the original standard tables. In general, three sky or Sun plates should furnish

sufficient data for a fundamental table, though the conditions obtaining in any particular case might call for a greater or smaller number.

This velocity-standard method is best applicable to solar-type stars, but it may, if desired, be modified to suit the requirements of hydrogen or other stars without the introduction of errors greater than those incident to present methods. Thus a standard table for any class of stars may be prepared by introducing in the spark, in addition to the regular comparison, those elements which produce good lines in the stellar spectra. The assumption is made that the relative positions of the spark and dark lines of the elements used are not affected differently either by the dissimilar physical conditions in the spark and star or by the peculiarities of the spectrograph; but this is an assumption commonly made in all spectrographic work.

PART II.

AN APPLICATION OF THE VELOCITY-STANDARD METHOD.

(a) *Apparatus employed.*—Necessity for some departure from the present methods of measurement and reduction of spectrograms first arose in the attempt to improve the accuracy of relative velocity determinations from spectrum plates made with *Spectrograph I* of the Lick Observatory. The performance of this spectrograph is exceptionally good. The limit of resolving power with lantern-slide plates is about 0.50 Å.U. at $H\gamma$, which is all that could be expected of an instrument of one fifth the dispersion of the Mills. However, with rapid emulsions, the increased size of silver grains interferes seriously with the definition. Careful tests by Dr. J. STEBBINS and Dr. J. H. MOORE have shown that all effects of flexure have been successfully eliminated in the construction of this instrument. But the effect of temperature change on the positions of lines is very marked. This is largely due to the unequal expansion in the triangle formed by the steel collimator tube, the brass camera tube, and the brass tie-rods which extend from the collimator tube nearly to the plate-holder. The extent of this shift has been determined by Dr. MOORE. It is equivalent to approximately 36 kilometers in velocity per degree Centigrade change in temperature. The limitations of the instrument are thus readily appreciated. In my own work, in the absence of

a temperature case, the spectrograph has been wrapped in several thicknesses of woolen blanket just before the exposure began. At the same time all the windows in the dome were closed. These precautions, together with the frequent introduction of the comparison, have made good results possible, but it has been almost invariably the case that the best velocity determinations have been made from plates for which the temperature range was a minimum. Recently a temperature case and automatic thermostat have been constructed for this instrument. These may be expected to result in very material improvement in its performance.

Further disadvantages are inherent in an instrument of low dispersion and resolving power. Linear defects in lines produce five times the error that they would occasion with the Mills spectrograph. Probably no more than fifteen or twenty single lines could be measured with any power on any one plate of a solar-type star. STEBBINS found only six coincidences of solar and stellar lines for α Ceti in a region of 340 Å.U., while in a region covering 120 Å.U. he found twenty such lines on Mills plates. With a power of ten, absolutely no single lines would be available for velocity determinations. In view of these facts, it would seem that few tests could be more exacting than the application of the velocity-standard method to this case. Spectrograms made with an instrument of this kind, with no greater protection against temperature change, are affected by errors which accurate measurements serve to bring out; but it was one aim of the author to determine the degree of accuracy to be expected from an instrument of low dispersion, for its field of usefulness is practically inexhaustible, as it reduces the exposure time required with the Mills spectrograph by ninety per cent.

(b) *Application to the study of the variable star, W Sagittarii.*—Exhaustive studies of the light curve of *W Sagittarii* were made by Herr J. H. F. SCHMIDT, who discovered the variability of this star, then known as γ' *Sagittarii*, at Athens in 1866.* From a series of eight hundred and ninety observations, covering ten years and extending over one hundred and ninety-five maxima and one hundred and ninety-three minima, he constructed a light curve, which is drawn in detail in Plate

* *Astronomische Nachrichten*, Nr. 2071, page 103.

8* of this paper. In addition to the strong irregularities in the curve, he suspected a perturbation in the light period running through a cycle of eight years, affecting the time of maximum and minimum several tenths of a day. But his observations were hardly extensive enough to warrant this last conclusion. The spectrographic observations at present available do not cover a period long enough to confirm or to disprove this result. As presented in the Chandler and Harvard catalogues, the important data regarding this star, with some additions, are as follows:—

Chandler's Third Catalogue.

Max., 4^m.8; Min., 5^m.8; M-m, 3^d.00; Period, 7^d.59460E.
Epoch of Max., 1866, Sept. 4; Julian, 2,402,849^d.45.

Harvard Catalogues.

Max., 4^m.3; Min., 5^m.1; Class IV; Sp., G5K.
a 1900.0, 17^h 58^m.6; δ 1900.0, — 29° 35'.

Additional Data.

λ 1902.0, 269° 44'; β 1902.0, — 6° 08'.
Photo. Max., 5^m.5; Photo. Min., 6^m.5.

The spectrum of *W Sagittarii* approximates very closely to the solar type. The fact that sixty-five blends ranging in intensity from twelve to forty gave good results, as exhibited in the last column of Table III,† establishes the close resemblance of this star to our own central body. The seventeen lines in Table IV† suggest some differences, the most striking of which is the strong line at λ 4335.7, which is not found in the Sun, but rises to an intensity of 12 in the star. But, on the whole, the identities are far-reaching enough to warrant an extensive system of blending.

This fact justified the use of a power of ten in the measures of the plates of *W Sagittarii*. But the selection of such a low power was not decided upon without considerable experiment with a higher one. With a power of ten, the width of the micrometer thread (about 0.50 Å.U.) interfered with settings on lines of intensity 12 to 15, while the density of the comparison lines was so great that it became difficult at times to

* Omitted in this abstract.

† Tables and details of reduction are omitted in this abstract.

distinguish the black vertical wire when set on them. After experimenting with powers of ten, twelve, fifteen, and twenty-five, I am inclined to think that a power in the neighborhood of fifteen would perform most satisfactorily in the case of solar-type stars.

From preliminary measures in August, 1903, of three spectrograms of *W Sagittarii*, a very considerable variation in the radial velocity of this star was brought to light. Subsequently a series of thirty-three spectrograms, distributed uniformly in the light period, was completed with Spectrograph I. These have been measured and reduced for the purpose of determining the character of the orbit of this interesting variable. I have not been able to recognize upon these plates any effect attributable to the light of the fainter companion now known to exist, but it should be remembered that a difference of one magnitude is nearly sufficient to obliterate the effect of the darker star.

Assuming the identity of the light and velocity periods for this star, we may lay down the plot of the velocity determinations by employing the intervals after maximum as abscissæ and the corresponding radial velocities of the star with respect to the Sun as ordinates. Ample verification of the adopted value for the period was found in the close agreement between results obtained from plates covering more than forty maxima of the curve, or an interval of 309 days. But when the attempt was made to pass an elliptic velocity curve through these observations, it was found that the plotted points oscillated above and below this curve with a period of 3.8 days, or one half that of the light variation. After repeated trials of various ellipses with different values of periastron time, longitude of periastron, eccentricity, maximum positive and negative velocity, and the velocity of the system, I selected the velocity curve which is drawn on Plate 8* with the narrower line. In selecting this conic it was assumed that the actual observed velocities followed a superimposed curve with a period of 3.8 days and with nearly equal amplitudes for crests and troughs. For the better determination of the secondary curve the residuals of all plates from the ellipse were plotted after being reduced to one complete period of 3.8 days, employing the well-

* Omitted in this abstract.

established nodal point at 1.7 days after the light maximum. A sine curve was then passed through these points with an amplitude of 4.2^{km} at the crest and 5.5^{km} at the trough. This final curve was superimposed on the velocity curve and is represented by the heavy line of the upper curve of Plate 8.* The residuals from this curve for all the plates appear in Table VII* under the heading r . Including all these residuals, and assigning equal weights to each, the resulting probable error of a single plate is $\pm 0.90^{\text{km}}$. Excluding five inferior plates whose velocities could be given very small weight in the construction of the curve, the probable error of any one of the remaining twenty-eight plates is $\pm 0.55^{\text{km}}$. The occurrence of relatively larger residuals along the crest of the secondary curve finds ready explanation when it is noticed that, of the two crests which obtain in one complete revolution of the system, the one occurs at the light maximum where the greater activity of the star could lead to wide ranges in velocity, while the other occurs at light minimum where, with increased exposure time, the effect of temperature change in the instrument becomes a maximum.

The elements of the orbital or primary curve of the brighter component of *W Sagittarii*, together with those of the superimposed secondary curve, as are follows:—

	ELEMENTS	Primary Curve.	Secondary Curve.
Apparent period,	P'	7.59460 days	3.80 days
Longitude of periastron,	ω	$70^{\circ}.0$	
Eccentricity,	e	0.320	0.0
Time of periastron after light maximum,	T	6.20 days	
Projection of semi-major axis on plane of sight,	$a \sin i$	$1.930,000^{\text{km}}$	
Projection of periastron distance on plane of sight,	$q \sin i$	$1,310,000^{\text{km}}$	
Projection of apastron distance on plane of sight,	$q' \sin i$	$2,550,000^{\text{km}}$	
Ratio of masses,	$\frac{m^3 \sin^3 i}{(m + m_1)^3}$	$0.00499 \odot$	
Amplitude of velocity curve at crest,	A	$+ 21.6^{\text{km}}$	$+ 4.2^{\text{km}}$
Amplitude of velocity curve at trough,	B	$- 17.4^{\text{km}}$	$- 5.5^{\text{km}}$
Velocity of center of mass of the system,	V'	$- 28.6^{\text{km}}$	

* Omitted in this abstract.

Our present knowledge of the elements of *W Sagittarii* makes possible the introduction of two small corrections to the period of this star depending upon the velocity of light. The first is due to the change in the distance between the Earth and the bright component of the binary system occasioned by their orbital motions, and may be regarded as the combined effect of the equations of light of the two bodies. Its operation is not systematic, but may be taken into account in the computed times for maxima used in plotting the velocity observations by changes never exceeding 0.01 days. The maximum variation from the mean in the present problem is about 0.002 days, which is equivalent to a displacement of 0.007^{cm} in the abscissæ of my original velocity diagram. It is therefore evident that this correction is negligible. The second correction to the period of this variable is based upon the continued approach of the system toward the Sun at the rate of 28.6^{km} per second. As this correction is constant, the use of the apparent period for the velocity diagram does not affect the determination of the elements which characterize the form and position of the orbit. But the epochs of the curve, referred to the time of maximum, and all dimensions of the orbit are direct functions of the true period. The correction to the apparent period amounts to + 62 seconds, or + 0.00072 days. Accordingly, the true value of the light and velocity periods of *W Sagittarii* is—

$$P = 7.59532 \text{ days.}$$

As the remaining elements of the velocity curve are published to three places only, this change in the fifth significant figure of P does not appreciably affect their values.

The angle i , which measures the inclination of the orbital plane to a plane tangent to the celestial sphere at the center of mass of the system, cannot be determined without micrometrical measures of the two components. The absolute scale of the ellipse is therefore indeterminate.

For purposes of comparison among spectroscopic studies of *Cepheid* variables, there exist in addition to the present investigation the excellent results of WRIGHT and BÉLOPOLSKY in connection with their researches regarding the orbits of $\delta \text{ Cephei}^*$ and of $\eta \text{ Aquilæ}^\dagger$. A strong resemblance between the

* *Astrophysical Journal*, Vol. I, page 160.

† *Astrophysical Journal*, Vol. VI, page 393. Ibid., Vol. IX, page 59.

elements of these stars is at once evident. All show a pronounced eccentricity. Also, the time of closest approach of the bodies of the system occurs about a day before maximum brightness. The most marked analogies exist between WRIGHT's elements of η *Aquilæ* and those of *W Sagittarii*; indeed, with the exception of a small difference in eccentricity, the uncertainty of inclination, and a difference of 0.5 days in the period, the two orbits are essentially identical even in regard to the positions of principal maximum and minimum. It is interesting to notice that Mr. WRIGHT has obtained no evidence of a secondary curve for η *Aquilæ*, but such a curve would not have been recognized if its amplitude did not exceed 2^{km} , and in some positions no great distortion of the ellipse would occur with an amplitude of five kilometers for the superimposed curve. Referring to Mr. WRIGHT's article, it should be noticed that the velocity curve reproduced there is the empirical curve which was drawn for the purpose of determining the elements. His actual ellipse passes slightly below observation 11, not above it. It will also be noticed that his observations tend above the published curve from 1 day to 2.8 days after maximum and fall below from 2.8 to 4.5 days. It therefore seems probable that some curve oscillating about an ellipse would represent the observations better.

Mr. WRIGHT's observations extend over four months, and my own over a period of less than a year. It is therefore probable that any influence connected with the long-period irregularities in the light recurrence of these stars would escape detection. Further study of these stars should reveal such phenomena.

The observed uniform correspondence between the light variations and the orbital conditions of these three stars suggests the mutual dependence of the two phenomena. Whatever may be the cause or causes of variation in the *Geminids*, they may not operate in the same manner in the *Cepheids*. It therefore seems advisable to treat each group separately in any attempt to construct a theory for the explanation of their light changes. I shall therefore advance some data regarding the most probable conditions that obtain in the system of *W Sagittarii*.

DARWIN'S expression for tidal potential is—

$$V = \frac{3m}{2r^3} \rho^2 (\cos^2 z - 1/3),$$

where r is the distance between the masses, ρ is the radius of the disturbed body, and z the angle between r and ρ ; m is the mass of the disturbing body. Confining our attention to the line joining the two bodies, we place $z = 0^\circ$ and differentiate with reference to the direction of displacement and arrive at the expression, $F = 2m\rho/r^3$, where F is the tidal force. As the ratio of apastron to periastron distance in this system is 2 to 1, it is evident that the tidal force varies in the ratio of 1 to 8 for these two positions. Using the rough conclusions as to the most probable data for the system arrived at above, we find that the intensity of the tidal force acting on the brighter body is, roughly, 50,000 times that of the Moon acting on the Earth. Further, by the introduction of another term usually negligible in tidal computations, we find the ratio of the intensities of the tidal forces on the side toward the disturbing body to the corresponding forces on the opposite side of the brighter star is 15 to 10 at periastron and 13 to 10 at apastron.

While the increase of light may be due to enormous tidal disruptions in the molten matter of the star's surface, accompanied perhaps with a liberation of heat from below, it should be noted that the displacements of the absorption lines in the spectrum are caused by the motions of the star's atmosphere with and relative to the regions emitting the light. In the atmospheric regions above the high tidal area there would undoubtedly be an uprush of gases due to atmospheric tides, convection currents, increased light pressure, and explosive outburst. Again, in the belt of low tide ninety degrees from the two high tides, there would probably be a corresponding recession of the atmosphere toward the star's surface. This would clearly give rise, in the actual velocity curve, to an oscillation with respect to a true ellipse. These oscillations would fall below the mean at conjunction and above the mean at elongation, for at conjunction the high tidal areas are presented to the observer, and at elongation the low tidal areas. Consulting the diagrams, this is found to be the case. We can there-

fore depart from the rotation theory to account for the secondary curve, and indeed this seems justifiable, for it is possible with the operation of such immense tides through long periods of time that the rotation periods of the stars involved should be brought to identity with the revolution period, as in case of our own satellite. Further, on the basis of the tidal theory, there would not seem to be sufficient variation in brightness due to difference in intensity of the tidal force between the two hemispheres (the ratio is about 7/5) to produce by rotation the oscillation observed, unless we assume much greater masses for the system. The occurrence of the light maximum when the tidal forces have fallen one third in intensity presents an anomaly, but it is possible that the effect of these forces lags to this extent.

Returning again to the rotation interpretation, it is easy to construct a plausible explanation for the light and velocity curves of *W Sagittarii* on the assumption that the system is pervaded by a resisting medium which enhances the brightness of that side of the star which faces the direction of motion. Or, again, a third body might be present in the system and give rise to the perturbations observed by SCHMIDT in the period. Until more data are available, to follow out such theories would be premature.

Considering all evidence, it seems reasonably certain that the star's variations in brightness, and particularly the principal variations, are attributable to the action of external forces.

It is a pleasure to acknowledge my indebtedness to Director CAMPBELL, who placed the necessary apparatus at my disposal and gave continual counsel and encouragement during the prosecution of the work, and to Dr. H. D. CURTIS and Dr. J. H. MOORE for valuable advice and assistance.

July, 1904.

RALPH H. CURTISS.



NOTICES FROM THE LICK OBSERVATORY.*

PREPARED BY MEMBERS OF THE STAFF.

CASTOR A QUADRUPLE STAR.

The second-magnitude star *Castor*, in the constellation *Gemini*, is known to all students of astronomy as a very interesting double star. In fact, Sir WILLIAM HERSCHEL, the pioneer of double-star astronomy, called it the largest and finest of all the double stars visible to observers in the northern hemisphere. It is also very interesting historically; for the motions in its system first convinced HERSCHEL that there are systems in which two or more bright stars are revolving around each other in orbits of short period.

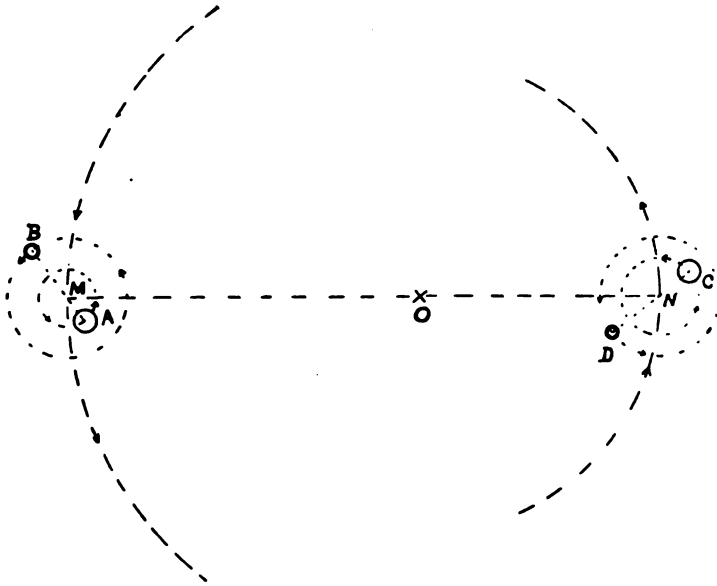
The two component stars of *Castor* are a little brighter than the third and fourth magnitudes, respectively. They are about five and one half seconds of arc apart, and revolve around their common center of mass in approximately three hundred and fifty years, according to the latest calculations. An uncertainty of one hundred years at least exists in this estimate, for the reason that accurate observations of the relative positions of the two stars have been made for less than one hundred years.

An interesting discovery concerning the fainter of the two components of *Castor* was made, nine years ago, by Astronomer BÉLOPOLSKY, of the Russian National Observatory at Pulkowa. While engaged in measuring the speed with which the two components are traveling to or from the observer, he discovered that the speed of the fainter component is variable. On one night the star would move toward the solar system; on another night it would move rapidly in the opposite direction, and later it would prove to be rapidly approach-

* Lick Astronomical Department of the University of California.

ing. A long series of observations has established that the speeds of this star pass through a complete cycle of change in a little less than three days. The explanation of the variable speed is, that this star is attended by an invisible and very close companion, massive enough to swing the bright star around in an elliptic orbit once every three days.

The purpose of this article is to call attention to the discovery, just made at the Lick Observatory, that the other and brighter component of *Castor* is likewise attended by an invisible component, which causes the speed of the bright star to



The System of *Castor*.

vary. At one time it is approaching us, and a few days later it is receding. The number of days required for the bright star and the invisible component to complete a revolution about their center of mass will not be known until a considerable number of observations have been secured, within the coming weeks. The discovery was made by Dr. CURTIS, using the Mills spectrograph attached to the 36-inch refractor.

In the accompanying illustration a rude attempt is made to illustrate the relationship of the stars in this system. A and C are the visible components of *Castor*. A is attended by

the invisible component B, discovered spectroscopically by BÉLOPOLSKY, and the two revolve around their center of mass, M, in slightly less than three days. The brighter star, C, is attended by the invisible companion, D, just discovered by Dr. CURTIS, and the two revolve around their center of mass, N, in a period as yet unknown. The two systems AB and CD revolve about their center of mass, O, in a period of approximately three hundred and fifty years. It should be said that the distances AB and CD are drawn relatively too large, and the distance MN vastly too small.

Great progress has been made in the study of double stars since the days of HERSCHEL. The known systems are numbered by the thousands, and the current work of Astronomers HUSSEY and AITKEN has established that, of stars brighter than the ninth magnitude, at least an average of one in eighteen is composed of two suns, visible in our great telescope. Although the components in each pair appear to be very close together, yet their distances from each other are so great, in all cases, that many years are required to complete one revolution. The shortest period, that of δ *Equulei*, is nearly six years. There are only thirty or forty whose periods are known to be less than one hundred years, and in the great majority of cases the periods will be expressed in hundreds and thousands of years.

The invention of the spectrograph, and its application to the measurement of stellar velocities of approach and recession, have enabled us to make a most interesting extension of our knowledge of binary systems. We are enabled to discover companion stars so close together that the most powerful telescope cannot separate them. In fact, their discovery becomes easier as the distance between the components becomes less. In the past few years more than a hundred such systems, known as spectroscopic binaries, have been discovered at a few of the leading observatories. It has in fact been established that, of the stars visible to the naked eye, at least one star in six is attended by an invisible companion, each so close to the bright component that the companion cannot be directly observed. In these systems the periods of revolution vary from one or two days, as a minimum, to a few years, as a maximum. For example, in the case of the North Pole star, the bright star and

an invisible companion revolve around each other in a period of four days, and this binary system and a second invisible component revolve around each other in from ten to twenty years. Easily the most interesting of all stellar systems thus far studied is that of *Castor*, as described above. It does not follow that the two invisible members of this quadruple system are really dark bodies. If they are two or three magnitudes fainter than the bright components, they would be invisible; for their light would be lost in that of the principal stars.

It should be said that the great value of the discovery of this interesting system lies not so much in the discovery itself as in the opportunity thereby afforded to study it thoroughly.

November 25, 1904.

W. W. CAMPBELL.

A DIVISION OF THE STARS IN SOME OF THE GLOBULAR CLUSTERS, ACCORDING TO MAGNITUDE.

The programme of observations for the Crossley reflector undertaken by the late Professor KEELER contained eight well-known globular star-clusters.

The general appearance of these clusters is very similar; they are of nearly the same angular dimensions, and the magnitudes of the component stars are remarkably alike.

In each of these clusters practically all of the stars can be separated into two classes of magnitudes. Perhaps a third of the whole number lie between eleventh and thirteenth magnitude, while almost all of the remainder are very faint, being about sixteenth magnitude. The appearance is that of two layers, one of bright stars superposed upon another of very faint stars.

But few stars of magnitudes fourteen to fifteen and one half are to be found in these clusters.

Photographs of the ω *Centauri* cluster obtained at the Harvard College Observatory station at Arequipa exhibit the same division of the stars in that cluster into two groups, as does the Crossley series. The limits of the area of the faint stars are fully as sharply defined as those of the brighter ones, and the centers of the two groups coincide. We are therefore led to the conclusion that in each case the observed division is in the same group of stars in space. That it is characteristic of all clusters of this type is not certain, but the lack of any

exceptions in the clusters observed strongly suggests such an hypothesis.

Two hypotheses to account for the peculiar distribution in magnitude suggest themselves: 1st. That it is due to a difference in the size of the stars; 2d. That it is due to a difference in constitution or physical condition.

The almost complete lack of physical data at present prevents any useful discussion of these hypotheses. Although the first appears to be the most probable, yet it is conceivable that this peculiar distribution might result from a difference in constitution of the stars themselves.

In this connection attention may be called to the relation which has been supposed to exist between the nebulae and the star-clusters. The belief has been gaining way since photography has shown the real structure of so many of these objects that they are but different stages in the process of evolution; that a star-cluster has been formed by the condensation of the matter in a nebula.

A study of the nebulae which have been observed with the Crossley reflector shows that a large proportion are spiral, and that practically all the spirals are lenticular or disk-shaped. Many of them are relatively very thin. Now, if the globular clusters are really spherical, as seems probable, it is difficult to see how they could have originated from a disk-shaped nebula (spiral?).

As there are other forms, also, of nebulae and star-clusters, it is not necessary to assume that the order of evolution mentioned above is the only one. But the natural tendency has been to connect such changes as these with the spirals which, by their appearance, seem to indicate greater systematic internal activity than others.

C. D. PERRINE.

July 17, 1904.

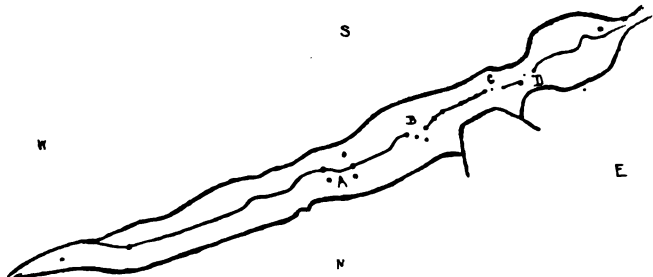
OBSERVATIONS OF A RILL EXTENDING THROUGH THE LUNAR VALLEY OF THE ALPS.

On the night of April 23, 1904, while showing the regular Saturday-night visitors the Moon through the 36-inch refractor, I noticed a rill at several points in the Alpine Valley. The seeing was too poor to make satisfactory observations, but at times the rill could be glimpsed for nearly the whole length of

the valley. It was observed on April 23d, May 6th, 22d, 23d, June 4th, July 2d, and August 30th, under both evening and morning illumination.

The rill extends the entire length of the valley, through the middle, and is continuous except at three points. It was suspected to cross one of these short gaps, and it is possible that, by observing diligently under good conditions, the rill could be traced across them all. It is visible only when the Moon is from eight to nine days, and twenty to twenty-one days, old. Owing to extreme narrowness,—the width is from three hundred to six hundred feet,—the rill can be seen only with a large telescope, and requires excellent atmospheric conditions.

The accompanying drawing is compiled from all the sketches. No attempt has been made to include details except such as are connected with the rill, or craterlets very near to it. Attention may be called to the great number of craterlets strung along the rill in some regions and to the fact that at all the gaps the rill terminates in craterlets.



Rill in the Valley of the Alps.

I have examined a number of the negatives of this region of the Moon, taken with the 36-inch refractor, especially those taken with an enlarging lens, but fail to find any trace of the rill upon them.

C. D. PERRINE.

October 16, 1904.

THE NUMBER OF THE NEBULÆ.

Professor KEELER, soon after beginning his program of work with the Crossley reflector, showed that the number of the nebulae is very much greater than had been supposed. He

conservatively placed the number within reach of that telescope at one hundred and twenty thousand. The recent completion of this program enables us to revise his estimate.

In fifty-seven regions seven hundred and forty-five *new nebulae* have been discovered. There were one hundred and forty-two known nebulae in these regions, making the total number of nebulae observed eight hundred and eighty-seven, an average of eight and one half per region. As it would take sixty-two thousand such photographs to cover the entire sky, the results indicate five hundred thousand as the corresponding number of nebulae within reach of the Crossley reflector. This assumes that the small portion observed represents fairly the entire sky.

Longer exposures, more sensitive plates, and more perfect photographs will undoubtedly reveal some nebulae which do not now appear and others which are confused with the faint stars. It seems probable, therefore, that the number of the nebulae will ultimately be found to exceed a million.

June 18, 1904.

C. D. PERRINE.

A NEW MOUNTING FOR THE CROSSLEY THREE-FOOT MIRROR.

The new mounting for this excellent mirror, which has been in the process of installation during the past year, was so far completed as to permit of its use in obtaining photographs of the ninth satellite of *Saturn*. The focus was determined (photographically) on November 5th, and on the following night observations of *Saturn* were begun. A few minor improvements have since been made, and some final adjustments are still necessary.

So far as it has been used, the telescope is very stable. No change of focus or collimation can be detected when the telescope is moved over a considerable range of zenith-distance.

A description of the telescope will be published soon.

November 28, 1904.

C. D. PERRINE.

THE TOTAL ECLIPSE OF SEPTEMBER 9, 1904.

A total eclipse of the Sun occurred on September 9, 1904. The shadow path crossed the central Pacific Ocean from west to east without touching known land, except that it reached

the coast of northern Chile six or eight minutes before sunset. Astronomer WILLIAM H. WRIGHT, in charge of the D. O. Mills Expedition from the Lick Observatory to Santiago, Chile, states that Dr. OBRECHT, Director of the National Observatory of Chile, established an observing-station at Taltal, but that the sky was cloudy at the time of totality. At Santiago, the sun set, partially eclipsed, on a fine horizon. W. W. C.

EXPERIMENTAL DETERMINATION OF THE SOLAR PARALLAX
FROM NEGATIVES OF *EROS* MADE WITH THE
CROSSLEY REFLECTOR.

In order to determine the value of the series of photographs of *Eros* which was made with the Crossley reflector, and to test a simple diurnal method of combining the results, six negatives were selected from the exposure of December 5, 1900. Three of the negatives were taken in the evening and three in the morning.

The measures and reductions were kept wholly in rectangular coordinates.

The result follows:

$$r_{\odot} = 8''.788 \pm 0''.008$$

The probable error of one equation of condition is $\pm 0''.022$. The probable errors of the position of one star upon a plate, being the mean of four exposures, are

$$\text{in } X = \pm 0''.08$$

$$\text{in } Y = \pm 0''.09$$

C. D. PERRINE.

OBSERVATIONS OF *PHEBE*, THE NINTH SATELLITE OF *SATURN*.

Photographs showing PICKERING's new satellite of *Saturn* were secured with the Crossley reflector on November 6th, 7th, 8th, 9th, and 10th, with exposures of one and three fourths to two hours. The satellite is of about the seventeenth photographic magnitude. A comparison of these observations with PICKERING's orbit gives no residual in position-angle, but in distance there is a difference of 1'.4, the satellite being nearer to the planet than indicated by the ephemeris. At the time of these observations, the satellite was 22' southwest of *Saturn*.

November 28, 1904.

C. D. PERRINE.

THE RADIAL VELOCITIES OF *S SAGITTÆ* AND *Y SAGITTARIÆ*.*

Measures of seven plates of *S Sagittæ*, employing the low-power sky standard-table described on page 249 have resulted in the detection of a wide range in the radial velocity of this star. As a whole, these plates are much below the average excellence, but are sufficiently reliable to establish the binary character of this variable. The accompanying table contains the number of the plate, the Greenwich date, the interval since maximum, the velocity referred to the Sun, the number of lines used for each plate, and the temperature change during the exposure. If the velocities are plotted in the usual way, assuming the identity of the light and velocity periods, they are seen to follow a curve in every way similar to those of *η Aquilæ* and *W Sagittarii*, and the elements will approximate closely to those determined for *W Sagittarii*. There is also some evidence pointing to a composite character for the curve.

No. Plate.	Date.	Interval since Maximum.	V.	Number of Lines.	Temperature Range.	Remarks.
28F	1903 Aug.	9.9	1 ^d .4 —20.3 ^{km}	20	0°.4C	Underexposed.
33E		14.9	6.4 —32.2	44	0.1	
35D		16.9	0.0 —30.2	45		
42B		26.9	1.6 —20.2	20	0.3	Underexposed.
54B	Sept.	6.9	4.2 —3.9	41	0.1	Comparison poor
72B		13.8	2.8 —17.3	37	0.0	on one side.
3350C	1904 July	20.9	3.7 —3.9	9	0.0	Underexposed.

As the result of relative measures of four lines on two plates, Dr. STEBBINS found a range of 9^{km} in the radial velocity of *Y Sagittarii*. My own measures of nine plates of this star indicate that it is approaching our system, but not at a constant rate. The range of velocity so far observed amounts to 17^{km}. The form of the curve seems quite different from that of other *Cepheid* variables, but the character and number of the plates available are not such as to warrant any definite conclusions on that point.

RALPH H. CURTISS.

July, 1904.

NEW COMPANIONS TO KNOWN DOUBLE STARS.

In the course of my search for new double stars I have recently found that one component in each of the well-known pairs, *Winnecke 3* and $\Sigma 2775$, is itself a close double star.

The former is the more interesting discovery, as the old

* From *Lick Observatory Bulletin*, No. 62.

pair is separated by less than 2", and has shown some change in angle, making it probable that we have here a ternary system. The pair Σ 2775 is so wide as to possess no interest, but the new pair, forming the principal component of the Struve pair, is certain to prove a binary. The positions of the stars for 1900, the mean of my measures, and an early measure of the old pairs for comparison, are as follows:—

<i>Winnecke</i> 3. R. A. 5 ^h 18 ^m 46 ^s ; Decl. —0° 58'.									
1904.85	141° .5	0".25	8.0—8.1	3 ⁿ	36-inch	B and C.			
4.85	160 .5	1 .87	7.7—7.8	3	36-inch	A and BC.			
1863.9	170 .7	1 .61	Measures by OTTO STRUVE.						
Σ 2775. R. A. 21 ^h 09 ^m 32 ^s ; Decl. —1° 15'.									
1904.71	43° .8	0".14	7.6—7.8	3 ⁿ	36-inch	A and B.			
4.67	177 .7	21 .27	7.2—10.5	1	36-inch	AB and C.			
1825.88	178 .8	21 .15	Measures by STRUVE.						
November 22, 1904.					R. G. AITKEN.				

DISTINGUISHED VISITORS TO THE LICK OBSERVATORY.

Of the many distinguished men of science who visited the Lick Observatory in recent months, the following may be mentioned:—

Professor SVANTE ARRHENIUS, of Stockholm. During his stay special interest was taken in the subject of the nature of the solar corona, and Professor ARRHENIUS embodied his views in a valuable paper. Inasmuch as he was at the time a member of the Faculty of the University of California, his paper was issued as a Bulletin of the Lick Observatory.

Professor HECKER, of the Royal Geodetic Institute, Potsdam. Magnetic observations were made at Mount Hamilton in connection with Professor HECKER's around-the-world survey.

Professor EMILE PICARD, Member of The Institute, Paris.

Professor HENRI POINCARÉ, Member of The Institute, Paris.

Professor H. H. TURNER, President of the Royal Astronomical Society, and Director of the Oxford Observatory.

Professors ARRHENIUS, PICARD, POINCARÉ, and TURNER were leading speakers at the St. Louis Scientific Congress.

W. W. C.

DUPLICITY OF 31 β LEONIS MINORIS.

The Durchmusterung magnitude of this star is 4.0. I have recently found it to be a close double. The companion is from two to three magnitudes fainter than the principal star, and situated in the direction 232° at a distance of not quite half a second.

From the character of this pair, I should at once say that it is probably a binary; that the two stars are physically connected is almost certain from the amount and direction of the proper motion. β Leonis Minoris is given in the fundamental star catalogues with a well-determined proper motion, amounting to $0''.164$ per year in the direction 225° . Were the two components not moving together, this would have been a very easy pair a few years ago, and its duplicity could hardly have escaped detection even by the meridian observers.

The position of the star for the epoch 1900 is

R.A. $10^h 22^m 6^s$; Decl. $+ 37^\circ 13'.2$.

W. J. HUSSEY.

ON THE SPECTRA OF *R SCUTI* AND *W CYGNI*.*

Observations of the spectra of *R Scuti* and *W Cygni* are particularly valuable, as these stars occupy a unique position between the short-period variables on the one hand and the *α Ceti* variables on the other. Visual observations of *R Scuti* by ESPIN have led him to suspect the presence of bright lines in its spectrum, but he seems to have been unable to identify them. As far as I know, *W Cygni* had not been observed with the spectroscope.

Exposures upon both these stars with Spectrograph I were begun in the middle of July, 1903. They were continued until November 11, 1903, in case of *R Scuti*, and December 28, 1903, in case of *W Cygni*. *R Scuti* was examined visually with the spectrograph until December 7th. In the mean time, *R Scuti* rose to maxima toward the end of July and the beginning of October, while maxima of *W Cygni* occurred early in August and in the middle of December. During this period about twenty-five spectrograms of *R Scuti* and twenty of *W Cygni* were secured with Spectrograph I.

* From *Lick Observatory Bulletin*, No. 62.

On plate 13E of *R Scuti*, $H\beta$, $H\gamma$, and $H\delta$ shone out strongly as bright lines, but they faded quickly until at minimum the spectrum of the star departed but little from the solar type, with dark hydrogen lines of customary intensity. At the two subsequent maxima the bright hydrogen lines were not seen, but the intensity of the absorption line at $H\gamma$ seemed to have decreased very much as the star approached its maximum of October. Judging from rough measures of a few plates, the radial velocity of this star appears to be constant and about $+42^{\text{km}}$ in actual value.

W Cygni shows a banded spectrum of a type characteristic of long-period variables. At the maximum of August, 1903, the hydrogen lines mentioned above appeared as strong bright lines which faded gradually to the star's minimum, while the absorption line at g broadened greatly during the same period. Other suspected bright lines in the spectrum of this star remain to be identified.

A detailed study of these plates will be made at the earliest opportunity.

RALPH H. CURTISS.

July, 1904.

GENERAL NOTES.

Our readers will remember that in 1899 Professor W. H. PICKERING announced the discovery, from plates taken in Peru in August, 1898, of a ninth satellite of *Saturn*. Months, even years, elapsed without any verification, either visual or photographic, of this discovery. Professor PICKERING has obtained many photographs of this tiny member of the solar system, and recently the interesting announcement was made that Professor BARNARD had seen and measured this object with the great telescope of the Yerkes Observatory.* The satellite has been called *Phæbe*, and Professor BARNARD estimates its visual magnitude to be 16.7.

Harvard College Observatory Annals (Vol. LIII, part 3), recently issued, gives in detail Professor PICKERING's work upon this object. The most interesting announcement concerning this new member of the solar system is, that its motion about *Saturn* is retrograde, while that of all the other satellites of *Saturn* is direct. The period of revolution about *Saturn* is 540.5 days, and the eccentricity of the orbit, 0.22, is greater than that of any other satellite or large planet, and is exceeded by only a few of the asteroids. As seen from *Saturn* the magnitude of *Phæbe*, when full, would vary between 5.2 and 6.2. Its diameter is estimated to be between one hundred and two hundred miles.

Dr. FRANK McCLEAN, of Tunbridge Wells and London, and a member of the Astronomical Society of the Pacific, died on the 8th of November last, in his sixty-seventh year. He was trained as a civil engineer, but relinquished professional work in 1870. A few years after his retirement he established an astronomical observatory at Tunbridge Wells, and from that time forward was much engaged on solar and stellar spectroscopic work. In 1880 he founded the Isaac Newton Studentship at Cambridge, where he had graduated as a Wrangler in 1860. In 1882 he was presented to the Royal Observatory at the

* See also the note on page 111, its observations by Professor PICKERING with the Cassini telescope.

Cape of Good Hope the Victoria photographic telescope, of 24-inch aperture. He afterwards discovered the presence of oxygen in the helium class of stars, and in 1899 was awarded the gold medal of the Royal Astronomical Society for his photographic survey of star spectra in both hemispheres and for other contributions to the advancement of astronomy. He was a Fellow of the Royal Society and also of the Royal Astronomical Society.—*London Standard*.

In *Harvard College Observatory Circular* (No. 88) Professor E. C. PICKERING announces the discovery, photographically, of a new variable of the *Algol* type. The star is in the constellation of *Sagittarius*, and is designated $-15^{\circ}. 4905$. Three hundred plates were available for the study of this star, and on twenty-eight of them it was found to be fainter than the normal brightness, 9.55.

"The observations indicate that the times of minimum may be represented by the formula $J. D. 2,410,002.677 + 3.45348 E$. An interesting feature in the variation is found in the fact that a secondary minimum occurs midway between the primary minima represented by the formula."

The first ordinary meeting of the Edinburgh Royal Society for the present session was held on the evening of November 7th in the Royal Institution, Mound—Lord M'LAREN, Vice-President, in the chair. Dr. J. HALM, Assistant Astronomer, Royal Observatory, Edinburgh, read a paper on Professor SEELIGER'S "Theory of Temporary Stars." The lecturer attempted an explanation of the peculiar features of the *Nova* spectrum on the basis of SEELIGER'S well-known hypothesis, according to which the outburst of a new star was due to the collision between a dark cosmic body and a cloud of tenuous nebular or meteoric matter. He showed that the peculiar displacements noticed in the spectral lines were due to motions of gaseous matter engendered by the impacts. Their ideas of these motions had hitherto been inadequate, because the influence of gravitation had been neglected. So far only the relative motion of the star against the nebula had been considered, the consequence being that assumptions became necessary which rendered the theory unacceptable. But the gravitational

attraction of the star on the cloud particles produced motions of such a character and magnitude that most of the hitherto enigmatic spectra features were brought within the range of physical explanation. From this point of view, two important conclusions might be reached. First, they were practically unlimited in their assumptions as to the amount of heat developed by the impact. It could be shown that a bombardment of the star by matter whose density was only the one two-thousand-millionth part of that of air at ordinary pressure and temperature was sufficient to produce an amount of heat equal to that radiated by the Sun into space. This stupendous heating of the star's surface was necessarily followed by the formation of an atmosphere of incandescent gases and vapors which expanded at an enormous rate. The velocity of these expanding gases might indeed be supposed to exceed even those noticed in solar eruptions. The author showed that the most important features of the typical *Nova* spectrum could be sufficiently accounted for by considering the motions of this expanding atmosphere. Especially noteworthy was the explanation from this point of view of the uniformity of type in the spectra of all the *Novæ* hitherto observed. The second conclusion was drawn from the consideration that the impact of the meteoric cloud must always be more or less unsymmetrical or one-sided. This was shown by the author to lead to the formation of a gyrating ring of incandescent nebular matter revolving round the star nucleus, with a speed probably not much less than four hundred kilometers per second. While the expanding atmosphere determined the appearance of the spectrum during the earlier stages, the orbital motion of matter in the ring became prominently apparent in the last period of the star's development. The two conclusions, which seemed to be unavoidable, if once the soundness of SEELIGER's fundamental assumption was admitted, were sufficient to explain the facts so far observed and to form a mental picture of the physical development of these celestial catastrophes in accordance with what had actually been noticed. The author laid particular stress on the fact that the observations pointed conclusively to DOPPLER's principle as the basis from which the features of the *Nova* spectrum must be explained, and he dwelt upon the difficulties which were experienced if the problem was approached from other

points of view. He also suggested that his second conclusion—viz., the formation of a permanent rotating ring round the star in consequence of one-sided collision—might perhaps account for the origin of the rotation of our own solar system. He pointed out the serious objections to LAPLACE's conception of the original solar nebula, in which this rotation had to be supposed as a pre-existing quality of the solar matter, and thought that this new point of view, which assumed as the starting-point of solar evolution the encounter between the Sun and a cosmic cloud of considerable density, besides affording an explanation of the origin of rotation, would be less open to the mathematical criticism to which LAPLACE's theory had in recent times been so severely submitted. All conclusions seemed to point in the one direction, that the solar nebula, during its primordial stage, must have been heterogeneous to a degree in no way compatible with the Laplacian conceptions, but quite imaginable if a collision of the kind here indicated was accepted. Communications were also read by Dr. MUIR on the "Sum of the Signed Primary Minors of a Determinant," on "Continuants Resolvable into Linear Factors," and on the "Three Line Determinants of a Six-by-Three Array."—*Extract from the Scotsman.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS,
HELD IN THE ROOMS OF THE SOCIETY, NOVEMBER 26,
1904, AT 7:30 P.M.

President EDWARDS presided. A quorum was present. The minutes of the last meeting were approved.

The following resolutions were adopted to fill the vacancies caused by the death of Mr. WM. M. PIERSON:

Resolved, That Dr. HARRY EAST MILLER be appointed a member of the Board of Directors, A. S. P.

Resolved, That Mr. WM. H. CROCKER be appointed a member of the Donohoe Comet-Medal Committee.

The question of filling the vacancy on the Finance Committee was laid upon the table.

It was, upon motion,—

Resolved, That no award of the Bruce Medal be made for the year 1905.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY
OF THE PACIFIC, HELD IN THE LECTURE HALL OF
THE CALIFORNIA ACADEMY OF SCIENCES,
NOVEMBER 26, 1904, AT 8 P.M.

The meeting was called to order by President EDWARDS. The minutes of the last meeting were approved.

The chairman introduced the lecturers of the evening: Dr. S. D. TOWNLEY, who read a paper on "The Motion of the Earth's Axis"; and Dr. HEBER D. CURTIS, whose paper was entitled "Spectroscopic Binaries." Both lectures were illustrated by a number of lantern-slides.

WILLIAM MONTGOMERY PIERSON died at his home in San Francisco on the fourth day of September, 1904. He was born in Cincinnati, Ohio, on February 3, 1842, and came to California in the year 1852.

Mr. PIERSON studied law while very young, and successfully passed the legal examinations before he arrived at the age of twenty-one years. He was permitted to enter upon his chosen career before reaching his majority, by special act of the Legislature, approved March 20, 1862. During his long career as an attorney at law he became one of the most eminent members of the legal profession on this Coast.

Notwithstanding his active business life, he found time to devote himself to the sciences, of which Astronomy claimed his special

interest. He took a prominent part in the organization of the Astronomical Society of the Pacific at its first meeting, on February 7, 1889; he was its first Vice-President, its second President, and, from its foundation until his untimely death, a member of the Board of Directors, and of the Finance and Comet-Medal Committees.

In addition to his continuous efforts to promote the welfare of the Society, he fitted out, at his own expense, an expedition to observe the Total Solar Eclipse in India in 1898, from which important scientific results were obtained; he enriched the equipment of three astronomical observatories in California by gifts of valuable instruments, and made generous financial contributions to this Society in time of need. For fifteen years he was the legal adviser of the Board of Directors of the Astronomical Society of the Pacific, and was ever prepared to give to the Society the benefit of his sound judgment and advice. In him this Society has lost one of its truest friends.

A committee appointed by President EDWARDS, consisting of Messrs. BURCKHALTER, CUSHING, and ZIEL, presented the following resolutions on behalf of the members of the Astronomical Society of the Pacific:—

In Memoriam.

WHEREAS, WILLIAM MONTGOMERY PIERSON, a Charter Member, an ex-President, and a member of the Board of Directors from the foundation of the Society, has been claimed by death; and

WHEREAS, Mr. PIERSON was foremost in promoting the welfare of the Society, by his wise counsel and generous financial aid; therefore be it

Resolved, That in the death of this distinguished citizen this community has suffered a severe loss, and this Society one that is irreparable; and astronomical science a friend, willing both to do and to give;

Resolved, That, whether as members of this Society or as his personal friends, we have each sustained an individual loss;

Resolved, That in token of our appreciation of his effective help and of our love for him, these resolutions be spread in full on our minutes, and that a copy thereof be sent with our heartfelt sympathy to the bereaved family of our departed friend.

SAN FRANCISCO, November 15, 1904.

ASTRONOMICAL SOCIETY OF THE PACIFIC.

CHARLES BURCKHALTER,

CHAS. S. CUSHING,

F. R. ZIEL,

Special Committee.

Adjourned.

278 *Publications of the Astronomical Society, &c.*

OFFICERS OF THE SOCIETY.

Mr. GEO. C. EDWARDS *President*
 Mr. S. D. TOWNLEY *First Vice-President*
 Mr. CHAS. S. CUSHING *Second Vice-President*
 Mr. A. O. LEUSCHNER *Third Vice-President*
 Mr. R. G. AITKEN } *Secretaries*
 Mr. F. R. ZIEL }

Mr. F. R. ZIEL *Treasurer*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CROCKER, CUSHING, EDWARDS, LEUSCHNER, MILLER, PARDEE, TOWNLEY, ZIEL.

Finance Committee—Messrs. CUSHING, LEUSCHNER, ———.

Committee on Publication—Messrs. AITKEN, SCHLESINGER, TOWNLEY.

Library Committee—Messrs. TOWNLEY, BABCOCK, MISS O'HALLORAN.

Committee on the Comet-Medal—Messrs. CAMPBELL (*ex-officio*), CROCKER, BURCKHALTER.

OFFICERS OF THE CHICAGO SECTION.

Executive Committee—Mr. RUTHVEN W. PIKE.

OFFICERS OF THE MEXICAN SECTION.

Executive Committee—Mr. FELIPE VALLÉ.

NOTICE.

The attention of new members is called to Article VIII of the By-Laws, which provides that the annual subscription, paid on election, covers the *calendar* year only. Subsequent annual payments are due on January 1st of each succeeding calendar year. This rule is necessary in order to make our book keeping as simple as possible. Dues sent by mail should be directed to Astronomical Society of the Pacific, 819 Market Street, San Francisco.

It is intended that each member of the Society shall receive a copy of each one of the *Publications* for the year in which he was elected to membership and for all subsequent years. If there have been (unfortunately) any omissions in this matter, it is requested that the Secretaries be at once notified, in order that the missing numbers may be supplied. Members are requested to preserve the copies of the *Publications* of the Society as sent to them. Once each year a title-page and contents of the preceding numbers will also be sent to the members, who can then bind the numbers together into a volume. Complete volumes for past years will also be supplied, to members only, so far as the stock in hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Any non-resident member within the United States can obtain books from the Society's library by sending his library card with ten cents in stamps to the Secretary A. S. P., 819 Market Street, San Francisco, who will return the book and the card.

The Committee on Publication desires to say that the order in which papers are printed in the *Publications* is decided simply by convenience. In a general way, those papers are printed first which are earliest accepted for publication. It is not possible to send proof sheets of papers to be printed to authors whose residence is not within the United States. The responsibility for the views expressed in the papers printed rests with the writers, and is not assumed by the Society itself.

The titles of papers for reading should be communicated to either of the Secretaries as early as possible, as well as any changes in addresses. The Secretary in San Francisco will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price, as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage, and should be remitted by money-order or in U. S. postage stamps. The sendings are at the risk of the member.

Those members who propose to attend the meetings at Mount Hamilton during the summer should communicate with "The Secretary Astronomical Society of the Pacific" at the rooms of the Society, 819 Market Street, San Francisco, in order that arrangements may be made for transportation, lodging, etc.

PUBLICATIONS ISSUED BI-MONTHLY.

(February, April, June, August, October, December.)



INDEX TO VOLUME XVI.

<p>AITKEN, R. G., The Double Star $\sigma 21$, 215; Elements of Comet a 1904 (with J. D. MADDRILL), 145; A New Companion to Σ 1506 and Two New Naked-Eye Double Stars, 119; New Companion to Two Known Double Stars, 268; Note on Comet Brooks, 34; Note on Comet a 1904, 145; Note on β 346 = <i>Libra</i> 23, 144; On Double Stars, 235; One Hundred and Fifty-five New Double Stars, 217; Recent Measures of ϵ <i>Hydra</i> AB, 118; Review of The Moon by W. H. PICKERING, 42; Unsuccessful Search for Periodic Comets</p> <p>ALBRECHT, SEBASTIAN, Photographs of BORRELLY's Comet, 1903 c</p> <p>ARRHENIUS, SVANTE, The Sun's Corona (abstract)</p> <p>Asteroids, The Watson, by B. L. NEWKIRK</p> <p>Astronomical Observations in 1903, by TORVALD KÖHL</p> <p>Astronomical Society of the Pacific:—</p> <p style="padding-left: 20px;">Address of the Retiring President of the</p> <p style="padding-left: 20px;">Award of the Bruce Medal of the</p> <p style="padding-left: 20px;">Award of the Donohoe Comet Medal of the</p> <p style="padding-left: 20px;">Annual Report of the Treasurer of the</p> <p style="padding-left: 20px;">Catalogue of the Library of the</p> <p style="padding-left: 20px;">Corresponding Institutions of the</p> <p style="padding-left: 20px;">Exchanges of the</p> <p style="padding-left: 20px;">Members of the</p> <p style="padding-left: 20px;">Minutes of Meetings of the</p> <p style="padding-left: 20px;">Minutes of Meetings of the Board of Directors of the</p> <p style="padding-left: 40px;">46, 124, 125, 131, 276</p> <p style="padding-left: 20px;">Officers of the</p> <p style="padding-left: 40px;">47, 132, 155, 233, 278</p> <p>Axes of Large Telescopes, The Supporting and Counter-Weighting of the Principal, by C. D. PERRINE</p> <p>BREDICHIN, THEODORE, Note on the Death of</p> <p>Bruce Medal, Award to Sir WILLIAM HUGGINS of the</p> <p>CAMPBELL, W. W., <i>Castor</i> a Quadruple Star, 260; Distinguished Visitors to the Lick Observatory, 269; Honors for, 119; Introductory Remarks at the Dedication of the Students' Observatory at Berkeley, 65; Lalande Prize Awarded to, 32; Note on ARRHENIUS's Paper on the Sun's Corona, 220; Note on the Observatory of the D. O. Mills Expedition to Chile, 144; Note on the Total Eclipse of September 9, 1904, 266; The Crocker Eclipse Expedition in 1905</p>	<p>216</p> <p>62</p> <p>220</p> <p>85</p> <p>25</p> <p>—</p> <p>49</p> <p>49, 124</p> <p>103, 232</p> <p>127</p> <p>157</p> <p>10</p> <p>11</p> <p>1</p> <p>46, 126, 276</p> <p>46, 124, 125, 131, 276</p> <p>47, 132, 155, 233, 278</p> <p>97</p> <p>228</p> <p>49, 124</p> <p>—</p> <p>217</p>
--	--

Catalogue of the Library of the Astronomical Society of the Pacific, by S. D. TOWNLEY	157
CHESTER, C. M., Report on the Naval Observatory, Washington, D. C., for 1903	104
Climatology of California, by A. G. McADIE, Review of by S. D. TOWNLEY	150
Comet :—	
Brooks, Note on, by R. G. AITKEN	34
a 1904, Elements of, by R. G. AITKEN and J. D. MADDRILL	145
Note on, by R. G. AITKEN	145
BORRELLY's, Photographs of, by S. ALBRECHT	62
Comets, Note on the Unsuccessful Search for Periodic, by R. G. AITKEN	216
COMSTOCK, G. C., Report on the Washburn Observatory for 1903	112
Constant of Refraction, The, by R. T. CRAWFORD	78
CRAWFORD, R. T., The Constant of Refraction	78
CURTIS, H. D., A Brief Review of Recent Progress in Solar Physics, 133; Definitive Orbit of the Spectroscopic Binary <i>i Pegasi</i> , 117; On Some Results Obtained by the D. O. Mills Expedition to the Southern Hemisphere	222
CURTISS, R. H., A Proposed Method for the Measurement and Reduction of Spectrograms for the Determination of the Radial Velocities of Celestial Objects, with an Application to a Study of the Variable Star <i>IV Sagittarii</i> , 243; On the Spectra of <i>R Scuti</i> and <i>W Cygni</i> , 270; The Radial Velocities of <i>S Sagittæ</i> and <i>V Sagittarii</i>	268
D. O. Mills Expedition to Chile, Note on the Observatory of the, by W. W. CAMPBELL	144
Dedication of the Students' Observatory at Berkeley	65
Double Stars :—	
<i>Castor</i> a Quadruple Star, by W. W. CAMPBELL	260
Duplicity of 31β <i>Leonis Minoris</i> , by W. J. HUSSEY	270
<i>Hydra</i> , AB, Recent Measures of, by R. G. AITKEN	118
A New Companion to Σ 1506, and Two New Naked-Eye Double Stars, by R. G. AITKEN	119
New Companions to Two Known Double Stars, by R. G. AITKEN	268
Note on β 346 = <i>Libra</i> 23, by R. G. AITKEN	144
Note on the Double Star O Σ 21, by R. G. AITKEN	215
Note on One Hundred and Fifty-five New Double Stars, by R. G. AITKEN	217
On Double Stars, by R. G. AITKEN	235
GELDERN, OTTO VON, Address of the Retiring President of the Society in Awarding the Bruce Medal to Sir WILLIAM HUGGINS	49

General Notes	35, 120, 146, 223, 272
GILLIHAN, A. F., The Photographic Equatorial of the Students' Observatory at Berkeley	89
GRIGG, J., A Brief Account of the Observatory at Thames, New Zealand	28
HOWE, H. A., Report on the Chamberlin Observatory for 1903	107
HUGGINS, Sir WILLIAM, Award of the Bruce Medal to	49, 124
HUSSEY, W. J., Duplicity of 31β <i>Leonis Minoris</i>	270
Introductory Remarks at the Dedication of the Students' Observatory at Berkeley, by W. W. CAMPBELL	65
KÖHL, TORVALD, Astronomical Observations in 1903	25
LANGLEY, S. P., Report on the Astrophysical Observatory of the Smithsonian Institution for 1903	107
LEUSCHNER, A. O., History and Aims of the Students' Observatory at Berkeley	68
Lick Observatory:—	
Crocker Eclipse Expeditions of 1905	217
Distinguished Visitors to the	269
Lalande Prize Awarded to Director CAMPBELL	32
The Observatory of the D. O. Mills Expedition to Chile	144
On Some Results Obtained by the D. O. Mills Expedition to the Southern Hemisphere	222
New Mounting for the Crossley Three-foot Mirror	266
The Publication of the Crossley Reflector Photographs of Nebulæ and Star Clusters	219
Notices from the	32, 117, 144, 215, 260
Loss of Light by Absorption and Reflection in the 36-inch Objective, by J. H. MOORE	202
Loss of Light by Diffraction at a Narrow Slit, by J. H. MOORE	203
Lunar Rill in Valley of the Alps, Observations of a, by C. D. PERRINE	264
<i>Lyra</i> , The Ring Nebula in, by B. L. NEWKIRK	13
MADDRILL, J. D., Elements of Corret <i>a</i> 1904 (with R. G. AITKEN)	145
MCCLEAN, FRANK, Note on the Death of	272
MCNEILL, M., Planetary Phenomena	29, 99, 141, 210, 212, 241
Meteors, Observations of, by TORVALD KÖHL	27
MILLER, J. A., Report on the Kirkwood Observatory for 1903	106
MONCK, W. H. S., The Sun's Velocity in Space	189
Moon, The, by W. H. PICKERING. Review of, by R. G. AITKEN	42
MOORE, J. H., Loss of Light by Absorption and Reflection in the 36-inch Objective, 202; Loss of Light by Diffraction at a Narrow Slit	203

NEWKIRK, B. L., The Ring Nebula in <i>Lyra</i> , 13; The Watson Asteroids	85
Observatories, Reports of, for 1903:—	
The Naval Observatory, Washington, D. C., by C. M. CHESTER	104
The Kirkwood Observatory, by J. A. MILLER	106
The Chamberlin Observatory, by H. A. HOWE	107
The Smithsonian Astrophysical Observatory, by S. P. LANGLEY	107
The Cincinnati Observatory, by J. G. PORTER	109
The Harvard College Observatory, by E. C. PICKERING	109
The Washburn Observatory, by G. C. COMSTOCK	112
The Vassar College Observatory	115
The International Latitude Observatory at Ukiah, by S. D. TOWNLEY	115
Observatory at Greenwich, Note on the Work of the	229
Observatory at Thames, New Zealand, a Brief Account of the, by J. GRIGG	28
O'HALLORAN, ROSE, A Few Details of the Twelve-Year Sunspot Cycle, 93; Variable Star Notes	101, 207
Nebulæ, The Number of the, by C. D. PERRINE	265
PERRINE, C. D., A Division of the Stars in Some of the Globular Clusters, According to Magnitude, 263; Experimental Determination of the Solar Parallax from Negatives of <i>Eros</i> Made with the Crossley Reflector, 267; A New Mounting for the Crossley Three-foot Mirror, 266; The Number of the Nebulæ, 265; Observations of a Rill Extending through the Lunar Valley of the Alps, 264; Observations of <i>Phæbe</i> , the Ninth Satellite of <i>Saturn</i> , 267; The Supporting and Counterweighting of the Principal Axes of Large Telescopes	97
Photographic Equatorial of the Students' Observatory, The, by A. F. GILLIHAN	89
PICKERING, E. C., Report on the Harvard College Observatory for 1903	109
Planetary Phenomena, by M. McNEILL	29, 99, 141, 210, 212, 241
PORTER, J. G., Report on the Cincinnati Observatory for 1903	109
Radial Velocities of <i>S Sagittæ</i> and <i>Y Sagittarii</i> , The, by R. H. CURTISS	268
Refraction, The Constant of, by R. T. CRAWFORD	78
Ring Nebula in <i>Lyra</i> , The, by B. L. NEWKIRK	13
ROBERTS, ISAAC, Note on the Death of	228
<i>Saturn</i> , Observations of <i>Phæbe</i> , the Ninth Satellite of, by C. D. PERRINE, 267; Note on	272
SMITH, ELLIOTT, Star Catalogues	193
Solar Parallax, Experimental Determination of the, by C. D. PERRINE	267

Solar Physics, A Brief Review of Recent Progress in, by H. D. CURTIS	133
Spectra of <i>R Scuti</i> and <i>W Cygni</i> , On the, by R. H. CURTISS	270
Spectrograms, A Proposed Method for the Measurement and Reduction of, for the Determination of the Radial Velocities of Celestial Objects, with Application to a Study of the Variable Star <i>W Sagittarii</i> , by R. H. CURTISS	243
Spectroscopic Binary <i>i Pegasi</i> , The Definitive Orbit of the, by H. D. CURTIS	117
Star Catalogues, by E. SMITH	193
Star Clusters, A Division of the Stars in Some of the Globular, According to Magnitude, by C. D. PERRINE	263
Students' Observatory at Berkeley:—	
Dedication of the	65
History and Aim of the, by A. O. LEUSCHNER	68
The Photographic Equatorial of the, by A. F. GILLIHAN	89
Sunspot Cycle, A Few Details of the Twelve-Year, by ROSE O'HALLORAN	93
Sun's Corona, The, by S. ARRHENIUS (Abstract)	220
Sun's Velocity in Space, The, by W. H. S. MONCK	189
Time-Signals from Washington, D. C., Note on	33
Total Eclipse of September 9, 1904, Note on the, by W. W. CAMPBELL	266
TOWNLEY, S. D., Catalogue of the Library of the Astronomical Society of the Pacific, 157; Note on Miss DOBBIN'S Orbit of the Fifth Satellite of <i>Jupiter</i> , 223; Note on Mr. HINK'S Work on <i>Eros</i> , 225; Report on the International Latitude Observatory at Ukiah for 1903, 115; Review of the Climatology of California by A. G. McADIE, 150; Summary of Recent International Latitude Work	147
Variable Stars, Observations of, by TORVALD KÖHL	25
Observations of, by ROSE O'HALLORAN	101, 207



CONTENTS.

	181
Aitken, R. G. On Double Stars	235
McNeill, M. Planetary Phenomena for January and February, 1905	241
Curtiss, R. H. I. A Proposed Method for the Measurement and Reduction of Spectrograms for the Determination of the Radial Velocities of Celestial Objects. II. Application to a Study of the Variable Star <i>β Sagittarii</i>	243
Notices from the Lick Observatory	260
General Notes	272
Minutes of Meeting of Directors	275
Minutes of Meeting of the Society	276
Officers of the Society	278
Index to Volume XVI	279



DOES NOT CIRCULATE



